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# DRAFT CONCEPTUAL RESTORATION PLAN FOR THE CLARK FORK RIVER AND BLACKFOOT RIVER NEAR MILLTOWN DAM

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## PREPARED FOR:

State of Montana, Natural Resource Damage Program and Department of Fish, Wildlife and Parks,  
in consultation with the U.S. Fish and Wildlife Service and Confederated Salish and Kootenai  
Tribes.

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# TABLE OF CONTENTS

|   | PAGE      |
|---|-----------|
| <b>1.0 INTRODUCTION (GOALS AND OBJECTIVES)</b>  | <b>1</b>  |
| <b>2.0 GEOMORPHIC OVERVIEW, REACH DELINEATION AND DESCRIPTIONS</b>                    | <b>3</b>  |
| 2.1 GEOMORPHIC OVERVIEW   | 3         |
| 2.2 UPSTREAM AND DOWNSTREAM LIMITS OF THE DIRECT AND INDIRECT EFFECTS OF MILLTOWN DAM | 4         |
| 2.3 REACH DELINEATION OF RIVERS IN PROJECT AREA                                       | 6         |
| 2.4 EXISTING AND POTENTIAL RESTORED CONDITIONS  | 7         |
| <b>3.0 HYDROLOGY AND FLOOD SERIES ANALYSIS</b>  | <b>11</b> |
| 3.1 GENERAL DESCRIPTION   | 11        |
| 3.2 HYDROGRAPHIC DISCUSSION   | 11        |
| <b>4.0 CHANNEL DIMENSIONS AND HYDRAULIC ANALYSIS</b>                                  | <b>13</b> |
| 4.1 CHANNEL AND FLOODPLAIN DIMENSIONS   | 13        |
| 4.1.1 OVERVIEW  | 13        |
| 4.1.2 CHANNEL DIMENSIONS  | 14        |
| 4.2 PLAN FORM GEOMETRY  | 17        |
| 4.3 HYDRAULIC ANALYSIS  | 17        |
| <b>5.0 PROPOSED RESTORATION STRATEGY AND RECOMMENDATIONS</b>                          | <b>18</b> |
| 5.1 COMPARISON OF EPA’S PROPOSED PLAN TO THE CRP                                      | 18        |
| 5.2 PLAN VIEW, LONGITUDINAL PROFILE, CROSS SECTIONS                                   | 20        |
| 5.3 PROPOSED CHANNEL FEATURES, STRUCTURES AND DETAILS                                 | 21        |
| 5.3.1 CFR 1 AND POWERHOUSE  | 21        |
| 5.3.2 CFR 2   | 23        |
| 5.3.3 CFR 3   | 25        |
| 5.3.4 CFR 4   | 26        |
| 5.3.5 BFR 1   | 26        |
| 5.3.6 BFR 2   | 27        |
| 5.4 CHANNEL CONSTRUCTION AND RESTORATION TECHNIQUES                                   | 27        |
| 5.4.1 CHANNEL CONSTRUCTION  | 27        |
| 5.4.2 BANK STABILIZATION STRUCTURES   | 30        |
| 5.4.3 GRADE CONTROL STRUCTURES  | 31        |
| 5.4.4 ADDITIONAL GRADE CONTROL STRUCTURES   | 34        |
| 5.4.5 SUMMARY OF RE-VEGETATION PLAN   | 35        |
| 5.5 BRIDGE RECOMMENDATIONS  | 37        |
| 5.6 TIMELINE AND CONSTRUCTION SEQUENCING  | 40        |
| 5.7 PHASE 2 NEEDS   | 41        |
| 5.8 PHASE 3 FINAL DESIGN NEEDS  | 41        |
| 5.9 MONITORING NEEDS  | 42        |
| 5.10 MAINTENANCE NEEDS  | 43        |

|            |   |           |
|------------|---|-----------|
| <b>6.0</b> | <b>COST ANALYSIS</b>                          | <b>43</b> |
| 6.1        | COST DISCUSSION                               | 44        |
| 6.2        | RE-VEGETATION COST REFERENCES AND ASSUMPTIONS | 46        |
| 6.3        | CONTINGENCY                                   | 48        |
| <b>7.0</b> | <b>REFERENCES</b>                             | <b>48</b> |

## TABLES

|           |  |    |
|-----------|--|----|
| TABLE 1:  | PREDICTED BANKFULL DISCHARGE   | 12 |
| TABLE 2:  | DISCHARGE ASSOCIATED WITH RECURRENCE INTERVAL  | 13 |
| TABLE 3:  | CFR C4 (UPSTREAM) STREAM TYPE  | 14 |
| TABLE 4:  | CFR B3 (UPSTREAM) STREAM TYPE  | 15 |
| TABLE 5:  | CFR B3 (UPSTREAM) STREAM TYPE  | 15 |
| TABLE 6:  | CFR B3 (DOWNSTREAM) STREAM TYPE  | 16 |
| TABLE 7:  | SUMMARY OF BANKFULL CHANNEL DESIGN DIMENSIONS  | 16 |
| TABLE 8:  | SUMMARY BY REACHES   | 17 |
| TABLE 9:  | PROPOSED CHANNEL AND REACH DIMENSIONS  | 21 |
| TABLE 10: | PROPOSED FISH HABITAT, GRADE CONTROL, BANK STABILIZATION,<br>AND RIVER BOATING STRUCTURES              | 29 |
| TABLE 11: | PROPOSED STRUCTURES DESIGNED TO PROVIDE GRADE CONTROL AND<br>STEP POOL MORPHOLOGY ON LOWER CFR AND BFR | 33 |

## APPENDICES

|              |  |
|--------------|--|
| Appendix 1:  | Display of the designated upstream limit of the backwater effect if the Dam compared to sediment Accumulation Areas IV and V.<br>Displays the selected reach delineations for the project areas. |
| Appendix 2:  | Photos of Reaches.   |
| Appendix 3:  | Cross-section templates for each set of channel dimensions.  |
| Appendix 4:  | Plan View Sheets (All).  |
| Appendix 5:  | Proposed Structures.<br>Example of how a combination of these structures could be placed in this reach.  |
| Appendix 6:  | Cost Estimate Sheets.  |
| Appendix 7:  | Conceptual cross-section of the proposed pedestrian bridge.<br>Representative Cross-Sections.<br>Longitudinal Profiles (LP's).   |
| Appendix 8:  | Cost analysis sheet for each structure.  |
| Appendix 9:  | Brown, et. Al. (2001) & Rosgen 1998  |
| Appendix 10: | Revegetation Photos  |

# **DRAFT CONCEPTUAL RESTORATION PLAN FOR THE CLARK FORK RIVER AND BLACKFOOT RIVER NEAR MILLTOWN DAM**

## **1.0 INTRODUCTION (GOALS AND OBJECTIVES)**

The State of Montana in consultation with other trustees, including the U.S. Fish and Wildlife Service and the Confederated Salish and Kootenai Tribes, contracted with Water Consulting, Inc. and Wildland Hydrology, Inc. to prepare a Conceptual Restoration Plan (CRP) and detailed cost estimate for restoration activities associated with the Milltown Reservoir Sediments Operable Unit. The CRP will integrate with and supplement Environmental Protection Agency's (EPA) Proposed Plan for removing Milltown dam and some of the polluted sediments deposited upstream of the dam.

It is contemplated that, due to time limitations and lack of site-specific data, the development of a complete restoration plan will be conducted in phases.

Phase 1 is this Conceptual Restoration Plan (CRP); this is a broad scale plan to provide restoration concepts, draft plan views and elevation information. The level of detail is adequate to provide the best possible cost estimate based on existing information.

Phase 2 would refine and validate the CRP with additional field data, analyses and surveys, including: additional topographic surveys; sediment entrainment data; bridge pier scour analyses; reference reach selection and data collection (Rosgen Levels 1 through 4 data); regional hydrologic analyses (using ongoing USGS work); field validation of proposed plan view and profile; ice potential and scour analysis; and peer review of potential recreational boating designs.

Phase 3 would be the final design phase, which will provide detailed design drawings and information adequate to permit and implement the project. This phase will include erosion control, revegetation, monitoring, maintenance, refined cost estimates, materials, equipment, implementation details and FEMA floodplain map revision analyses.

### **OBJECTIVES OF THE CRP**

The following objectives will be addressed in the CRP:

- ◆ Restore the confluence of the Blackfoot and Clark Fork Rivers to a naturally functioning, stable system appropriate for the geomorphic setting;
- ◆ Use native materials, to the extent practicable, for stabilizing channel, banks and floodplains to improve water quality by reducing bank erosion of contaminated sediments;



- ◆ Provide adequate channel and floodplain capacity to accommodate sediment transport and channel dynamics appropriate for the geomorphic setting;
- ◆ Provide high quality habitat for fish and wildlife, including continuous upstream and downstream migration for all native and coldwater fishes;
- ◆ Provide high quality wetlands and riparian communities, where feasible and appropriate for the proposed streamtype;
- ◆ Improve visual and aesthetic values through natural channel design, revegetation and the use of native plants and materials;
- ◆ Assess the pros and cons of removing or relocating the powerhouse and other dam structures not removed by remedy, with consideration of cost and integrity of remediation and restoration. Also consider the risk of damage to the restored reaches due to backwater effects during floods;
- ◆ Minimize habitats that will promote non-native, undesirable fish species;
- ◆ Supplement revegetation activities proposed by remedy to increase floodplain vegetation diversity; and
- ◆ Provide increased recreational opportunities compatible with other restoration goals, such as river boating and fishing.

This CRP differs from the EPA's proposed plan for remediation in that the concept of natural channel design techniques are used to create a stream system that includes an active channel designed to accommodate the normal annual high flow (bankfull discharge) and a floodplain that fits the geomorphic setting to accommodate flood flows. The traditional method employs standard engineering techniques that include an armored channel that will accommodate the 100-year flood within the channel banks. Natural channel design (NCD) aims to restore natural channel stability, or dynamic equilibrium and habitat to impaired streams (Brown, et al. 2001). Streams in dynamic equilibrium are generally more biologically productive, providing higher quality and more complex habitat than altered or unstable streams. When properly applied, NCD methods provide a robust, widely tested, and well-accepted approach to the design of natural channels that successively achieve habitat and geomorphic restoration objectives while functioning during extreme flood events (Schmetterling and Pierce, 1999). NCD is the foundation for developing a naturally stable channel design and meeting habitat restoration objectives.

The Rosgen Stream Classification System (RSCS) and reach characterization techniques are core to this methodology and in its rudimentary form, categorize streams into one of eight primary stream types (Rosgen, 1996; Bain and Stevenson, 1999). However, the RSCS is only an initial step to a complex protocol for temporally evaluating geomorphic stability, sediment availability and transport competency, and riparian condition. Geomorphic indicators (bankfull channel), prediction (reference reaches and dimensionless ratios), and method validation (regional curves) define naturally functioning channels. NCD focuses on restoring geomorphic characteristics while incorporating fish habitat structures composed of native materials in natural arrays that better replicate native salmonid habitat as necessary for restoring inland native fish populations.

For additional information on NCD, including Brown, et.al. (2001) and Rosgen (1998), refer to Appendix 9.

## **2.0 GEOMORPHIC OVERVIEW, REACH DELINEATION AND DESCRIPTIONS**

This section will describe the extents and limits of the project area, discuss the geomorphic setting, and provide an evaluation of the direct and indirect effects of Milltown dam. The extent of upstream effects of the Stimson diversion dam will also be discussed.

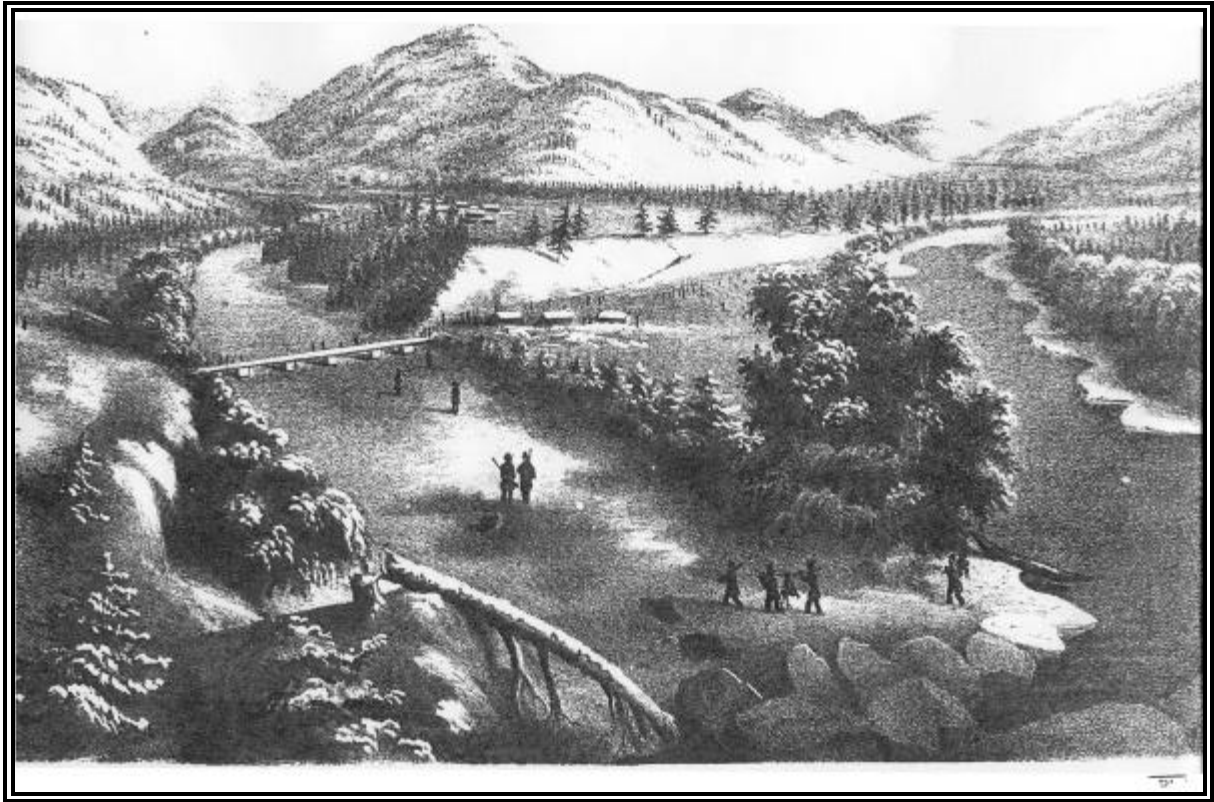
### **2.1 GEOMORPHIC OVERVIEW**

The Clark Fork River System is formed in a broad, low gradient, alluvial valley with a wide floodplain and adjacent terraces. Stream types in this setting tend to be C4 channels characterized by riffle-pool morphology and wide, flat, densely vegetated floodplains adjacent to the channels (Rosgen, 1996). These streams are highly sinuous, with bank stability related to dense rooting of shrubs and trees along the stream banks. Bed materials are predominantly gravel with some component of cobble and sand. These channels are highly prone to increased bank erosion and sediment supply when the vegetation is disturbed or the channel modified. The Clark Fork River just upstream from the confluence would naturally transition from a C4 channel to a B3c channel as the valley narrows due to confinement by the rock outcrop near the Milltown dam and the glacial outwash terrace from the Blackfoot River. Step-pool morphology and moderate width, sloping flood prone areas adjacent to the river characterize B3c stream types. A well-vegetated flood prone area allows for flood flows to spread out twice the width of the active channel, dissipating energy over a wider surface. The “c” designation indicates that the gradient is very low, in this case less than 0.005 ft./ft. B3c stream types have a low gradient, low sinuosity and tend to be very stable. Bed materials are predominantly large cobble, with some component of small boulder and gravel.

The Blackfoot River system and valley is dominated by glacial landforms, including moraines, glacial outwash terraces and lake sediments. In the lower Blackfoot River area near the confluence of the two rivers, the river has carved a fairly narrow valley through Belt series bedrock formations and either bedrock or coarse glacial outwash terraces that bound the Blackfoot River. Predominant stream types in this setting are B3c and F3 where the river has incised into the outwash terraces. F3 stream types are characterized by riffle-pool morphology and are deeply incised into a gentle gradient valley, which means that these streams do not have an adjacent floodplain. During a flood event, all the flow is contained within a narrow corridor rather than spreading out onto a floodplain. F3 stream types can be very stable in an un-altered condition. Sinuosity in this case is low, width:depth ratios are high and gradient is about 0.002 ft./ft. Bed materials are predominantly cobble, with some component of small boulder and gravel.

Where the two rivers converge, the valley narrows, confining the river between steep valley walls and coarse glacial outwash terraces. Historically, the Clark Fork River downstream from the confluence would naturally shift to a B3c or an F3 streamtype, depending on the degree of incision into the terrace. Stream gradient is about 0.002 ft./ft. The historic drawing of the confluence of the Clark Fork and Blackfoot Rivers during the winter of 1861-1862 provides a

depiction of the confluence area before the Dam and railroads were constructed. Whether this depiction is accurate is not certain; however, evaluation of this drawing indicates that both rivers were B3c type streams at the confluence. The Clark Fork valley appears to widen farther upstream in the drawing, with the River becoming less entrenched and more a C streamtype. A high glacial outwash terrace is also prominent at the confluence of the two rivers.



## **2.2 UPSTREAM AND DOWNSTREAM LIMITS OF THE DIRECT AND INDIRECT EFFECTS OF MILLTOWN DAM**

In order to effectively determine the components and costs necessary to restore the site, it is appropriate to stratify the project area into river reaches that have similar characteristics and restoration potential. One of the criteria that is necessary to determine costs and extent of treatment area is to evaluate where the upstream and downstream limits of the direct and indirect effects of Milltown dam. River reaches will be further stratified in the next section. For Milltown dam, all available survey data, aerial photos, the Federal Emergency Management Agency (FEMA), Flood Insurance Rate Maps (FIRM) (Aug. 1988) and field reviews were used to determine where the upstream extent of the backwater deposition. Specifically, the upstream limit of the effects of Milltown dam was determined from:



- The change in gradient (valley, streambed and flood profile) caused by the backwater effect of the dam during a large flood stage, such as the 1908 flood;
- The change in valley morphology and floodplain from a narrower floodplain with terraces to a broader floodplain with no terraces caused by backwater deposition burying the historic floodplains;
- The change in vegetation from coniferous species more common on the low terrace to deciduous species more common on the floodplain; and
- The uppermost extent of Sediment Accumulation Areas IV and V.

While it is not possible to determine the exact point on the Clark Fork River where the upstream effects of the dam end with the limited existing information, all four criteria placed the endpoint for the disturbance in a zone that was about 3,000 feet in length. The zone occurred from about 10,000 feet to about 13,000 feet upstream from the dam. For the limited purposes of this analysis and cost estimate, the upper limit of the backwater effects of the dam was selected at approximately the midpoint in this range at about 11,500 feet upstream from the dam. The actual upstream extent of the backwater deposition could be upstream or downstream by as much as 1,500 feet.

Please refer to Figure 2, Appendix 1 for a display of the designated upstream limit of the backwater effect of the Milltown dam compared to Sediment Accumulation Areas IV and V. This designated upstream limit will be a reach break point as described in Section 2.3. Refer to Section 2.4 for a more detailed description of processes associated with backwater deposition and the effects on individual reaches.

The effects of Milltown dam do not end at the dam structure, but also extend downstream on the Clark Fork River for a certain distance. It is not possible to determine the actual downstream extent of the influence of the dam with the limited available data and analyses. However, for the purposes of restoration, it is recommended that the restoration effort extend downstream to a stable point, as described in the next paragraph.

When combined with the river water that flows over the spillway, the large bay created by releases through the turbine gates creates a channel that is about twice as wide as the normal dimensions for the lower Clark Fork River. The river splits into two channels around an island that is probably the result of sediment deposition at the downstream end of the large pool where the two flow paths converge. The island and split channels could also be influenced by the railroad crossing downstream from Milltown dam. The overly wide area extends downstream past the railroad crossing to the point that the two channels converge. Just downstream from the point of convergence, the river transitions into a stable F type channel that appears to be functioning adequately at a point about 2,800 feet upstream from the I-90 bridge. For the limited purposes of this analysis and cost estimate, this point was selected as the downstream extent of the effects of the Milltown Dam.

In summary, the downstream effects include channel scour and over-widening from releases of water from the spillway and through the turbines. The island and split channels formed

downstream from the dam are most likely the result of the release patterns. The effect appears to end by Station 28+00. Also, the dam most likely traps and stores bedload sediment during normal high flow periods, which generally leads to a coarsening of the bed (increasing the particle size distribution) by causing the gravels to be scoured out of the reach without being replaced by upstream sources. This can influence habitat and productivity by reducing the amount of fine gravels that would be resident in the system.

The upstream extent of the backwater effects from Milltown dam on the Blackfoot River was determined based on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) longitudinal profile at larger flood stages and field reviews of the lower river. The FEMA profile indicates a distinct drop in water surface elevation at the Stimson diversion dam indicating a backwater effect from the diversion dam. Downstream from the Stimson diversion dam, the water surface is essentially flat at larger flood stages, indicating that the backwater effect from Milltown dam ends at the Stimson diversion dam. For this reason, the reach break on the Blackfoot River will be just downstream from the Stimson diversion dam.

There are other considerations that could influence the decision to include some of the costs of restoration of the Blackfoot River (BFR) upstream from Stimson diversion dam with the lower reach of the BFR. First, with Milltown dam removed, the Stimson diversion dam becomes a fish barrier year round. At present, the Stimson diversion dam may be a barrier only part of the year and therefore, removal of Milltown dam will have an effect on the upper BFR reach. Secondly, the drop in water surface elevation after Milltown dam is removed will create additional head (or drop) over Stimson diversion dam, which will increase the potential for scour and undercutting of the diversion dam. This increase in head could threaten the integrity of the Stimson diversion dam. Therefore, the Stimson diversion dam may be at an increased risk of failure following removal of Milltown dam.

### **2.3 REACH DELINEATION OF RIVERS IN PROJECT AREA**

The two rivers were delineated into reaches based on five criteria: 1) geomorphic setting of rivers; 2) potential streamtype for restoration; 3) degree of detailed information; 4) the upstream extent of the direct or indirect influence of Milltown dam, which was covered in Section 2.2.; and 5) the nearest stable point or unchanging feature upstream and downstream from the primary project area as described in the following discussion. Figure 1, Appendix 1 displays the selected reach delineations for the project area.

The rivers were divided into the following reaches:

- ◆ CFR 1 – Clark Fork from just upstream from the I-90 bridge upstream to the confluence of the rivers. The straight-line valley length of this reach is approximately 5,250 feet.
- ◆ CFR 2 - Clark Fork from the confluence upstream to approximately the Duck Bridge grade. The valley length of this reach is approximately 3,850 feet.
- ◆ CFR 3 – Clark Fork from Duck Bridge upstream to the upper most extent of the backwater deposition caused by Milltown dam as described in Section 2.2. The valley length of this reach is approximately 7,000 feet.

- ◆ CFR 4 - Clark Fork from Reach 3 upstream to include the Turah Bridge (and the nearest stable point). The valley length of this reach is approximately 15,400 feet.
- ◆ BFR 1 – Blackfoot from the confluence upstream to the Stimson diversion dam, as described in Section 2.2. The valley length of this reach is approximately 5,650 feet.
- ◆ BFR 2 – Blackfoot from Stimson diversion dam upstream until the backwater effect of diversion dam and channel constriction diminishes. Refer to Section 2.4, BFR2, for a description of the upstream endpoint. The valley length of this reach is approximately 6,500 feet.

See Appendix 2 for photographs of each of these reaches.

For a stream restoration project to be successful, it is important to start the restoration at the upstream extent of the unstable reach or altered reach of river. This is important to minimize the risk that the river will change its location or channel upstream from the project and enter the project at an inappropriate location. There are many case examples of the consequences of failing to extend the restoration upstream to a stable point or some other feature that will not change. Therefore, to minimize the risk of severe damage or failure of a restoration effort, a stable or unchanging feature must be identified. Since the Clark Fork River has highly altered in some reaches extending upstream to Deerlodge, MT, there was a need to identify some closer upstream endpoint. The Turah Bridge was selected as the upstream point because it is likely to remain in place in the future to provide access to private lands on the south side of the valley. As described in Section 2.4, the Clark Fork River is relatively unstable and highly altered upstream from Milltown dam all the way to the Turah Bridge. The bridge section can provide a relatively stable section from which to link the proposed restoration effort. Therefore, Reach CFR 4 is delineated as the upstream extent of the backwater effects of Milltown dam upstream to approximately the Turah Bridge.

As described in Section 2.2, downstream from Milltown dam, the stable endpoint for the restoration effort would be about 2800 feet upstream from the I-90 Bridge. However, for consistency in linking all the data sources together, the reach CFR 1 was extended downstream to the upstream edge of the I-90 bridge. For the remainder of the CRP, the upstream edge of I-90 bridge is labeled as Station 0+00 on the proposed longitudinal profile. There are no restoration treatments proposed for the 2800 feet between the I-90 bridge and Station 28+00.

A similar logic is applied to the Blackfoot River for Reach BFR 2. As described in Section 2.2, there is a backwater effect from the Stimson diversion dam also and the diversion dam is at an increased risk of damage or failure with the removal of Milltown dam. It would also become a fish migration barrier during most flow periods. Because of these factors and the need to extend the restoration up to a stable, upstream point, Reach BFR 2 was delineated and continues upstream to a stable point as discussed in Section 2.4, BFR 2.

## **2.4 EXISTING AND POTENTIAL RESTORED CONDITIONS**

The physical configurations of the two rivers have been highly modified by Milltown Dam and the deposit of industrial mining and other sediments, and to a lesser degree by other upstream influences. The Blackfoot River is directly affected by encroachment from Highway 200, fills at

the Stimson lumber mill, the Stimson diversion dam, highway bridges and the backwater effect caused by Milltown dam. The result is that the lower Blackfoot River downstream from the Stimson diversion dam is in the backwater of Milltown dam and is an F type channel. Upstream from Stimson diversion dam, the channel varies between an F channel and a B3c channel due to backwater sediment deposition and artificial elevation of the channel bed. The Clark Fork River is directly affected by similar impacts, in addition to encroachment and channelization by railroad grades.

The potential streamtype used for restoration is the most probable streamtype given the geomorphic and valley setting modified by the limitations imposed by human-caused or other influences that are not subject to change. For example, the most probable historic streamtype for a segment of river being evaluated may be a C type channel, but because of encroachment by a highway fill, the potential streamtype may be changed to a B type channel in a narrower valley. If more than one potential streamtype is possible, usually the most stable and productive streamtype is selected that will meet the objectives of the project.

### **CFR 1**

Milltown dam is in the upstream end of this reach and affects the channel both upstream and downstream, as described in Section 2.2. Historically, this channel would most likely have been a B3c streamtype in a fairly narrow valley bounded by a high glacial outwash terrace on the north and a bedrock valley wall to the south. The river transitions into a stable F3 streamtype between the dam and the I-90 bridge downstream. The existing channel is overly wide due to river flows being split between the spillway and turbine outlets. The large bay downstream from the dam is about twice as wide as the normal channel dimensions. The island that has formed downstream between the dam and the railroad crossing is a stable feature, but probably did not occur before the dam was constructed. However, the split channel presents some opportunities for side channel habitat and additional recreational experience. For these reasons, the proposed streamtype for the area between the confluence and the F3 type channel is a B3c with a diverging side channel that is less than 30 percent of the river flow during bankfull conditions. The valley gradient for this reach would be a constant 0.002 ft./ft. over a distance of about 5,250 feet.

### **CFR 2**

Before Milltown dam was constructed, this reach was most likely a transition zone between the wider valley and C type stream channel upstream to a narrower B type channel for some distance upstream from the confluence, as described in Section 2.1. A brief analysis was conducted for other valley transition reaches on the Blackfoot River, Clark Fork River and Rock Creek in similar geomorphic settings. The objective was to determine the potential length of the transition zone between a C type stream and a B type stream under natural conditions. Five transition reaches were located and evaluated for valley and channel characteristics. That information was used to determine that the transition zone for the CFR and BFR confluence area should be about 3,000 foot long. The meander geometry also changes somewhat in transition zones, and those values were calculated and used in the proposed plan view design (refer to Sheet CFR 2, Appendix 4).

The existing conditions were created shortly after Milltown dam was constructed. The dam created backwater conditions (ponding of the water, which reduces gradient and energy available for transporting sediment) extending upstream into Reach CFR 3. During the large flood of 1908, tremendous loads of sediment were deposited in the backwater zone upstream from the dam. The deposition filled existing channels, causing the river to create new channels in the path of least resistance. With no vegetation to stabilize the banks and a lower overall gradient, the channels tend to convert to a braided condition. During subsequent high flow years, the deposition progressed upstream, which reduces the gradient and energy available for moving sediment. The stream responds to the decrease in energy by filling the existing channel with bedload sediment and creating new channels in a similar fashion. The backwater effect of the Milltown dam was compounded by the Duck Bridge railroad crossing, which was a valley constriction and also created backwater conditions during large floods. The end result is a completely flat, braided plain that extends upstream into Reach CFR 3.

With the dam and contaminated sediments removed from Area I, the opportunity would exist to create a setting similar to the historic conditions. The proposed streamtype for CFR 2 is a C4 channel transitioning into a B3c channel. The valley gradient would increase from about 0.002 ft./ft. upstream from the Duck Bridge grade to about 0.005 ft./ft. in reach CFR 2. The valley length for Reach CFR 2 is about 3,850 feet.

### **CFR 3**

This reach was most likely a C4 channel historically with a wide, densely vegetated floodplain bounded by terraces. The existing situation is affected by backwater deposition from the Milltown Dam during flood events and the resultant channel system has changed into a braided D4 type system as discussed for Reach CFR 2. Sediment deposition has occurred for several thousand feet upstream, which has buried the historic terraces. The deposition and backwater from the dam has formed extensive wetlands, however, and vegetation communities have probably shifted from a mix of coniferous forests on the terraces and deciduous vegetation on the floodplain to predominantly deciduous and wetland vegetative types. The lower 2,200 feet of floodplain is essentially flat, corresponding to the normal high water conditions for the dam.

The potential streamtype in the area is a predominantly single thread C4 channel with off-channel wetlands supported by subsurface flows from adjacent hill slopes. The lower 2,200 feet of the channel and floodplain will need to be reconstructed at a lower elevation to prevent a flat discontinuity in the channel and valley gradient. The floodplain should span the belt width of the channel (width between the lateral extents of opposing meanders measured perpendicular to the slope of the valley). In other words, the valley gradient should remain at a constant 0.002 ft./ft. over a distance of about 7,000 feet. The floodplain should narrow gradually between the upstream and downstream segments.

### **CFR 4**

This reach is similar to CFR 3 except that it is upstream of the backwater deposition and effects of Milltown dam. The historic streamtype was most likely a C4 streamtype; however, channelization and encroachment from the highway and railroad grades have altered the channel and valley bottom significantly. Other influences include agriculture, grazing, timber removal, commercial, and residential development. Several sub-reaches of the Clark Fork within Reach

CFR 4 have responded to increased sediment supply and bank erosion by converting to a braided D4 type channel. These braided channels are typically highly unstable with bank erosion occurring on one or both banks almost continually along its length. High width:depth ratios reduce sediment transport capacity and in many cases D4 channels are in an aggrading trend (stream bed is elevated due to sediment deposition). The existing channel varies from C4 stream types to reaches of D4 and F4 stream types where the channel is either braiding or confined by berms, respectively. The potential streamtype is a C4 channel and can be created by re-activating abandoned meanders linked by new channel segments constructed to the appropriate dimensions. Overall floodplain width, belt width should remain unchanged and valley gradient will remain at about 0.003 ft./ft. over a distance of about 15,400 feet.

### **BFR 1**

The lower Blackfoot River was most likely a B3c channel upstream from the confluence before the Milltown dam was constructed. The glacial outwash terraces that confined the later extent of the floodplain remain, although the terraces are now highly developed for industrial, commercial, and residential land uses. The existing channel is affected by backwater conditions from the Milltown dam as well as five major highway and railway bridges. With the Milltown dam removed, the width between the terraces is sufficient to re-create a B3c channel type, similar to historic conditions. The five bridges complicate restoration, but would not prevent the conversion back to a B3c streamtype. The original gradient is unknown, but without reconstructing the bridges, the final gradient of the River will be dictated by the depth of the bridge piers and the allowable scour depth. The gradient would remain consistent at about 0.002 ft./ft. upstream from the Highway 200 Bridge, but would steepen to about 0.005 ft./ft. downstream to the confluence. For these reasons, the potential streamtype for BFR 1 is a B3c streamtype. A narrow, sloping flood prone area could be created by reshaping the channel cross section and redefining the thalweg. The valley length of this reach is about 5,650 feet.

### **BFR 2**

The upper Blackfoot River reach was most likely similar to the lower reach and was probably a B3c channel type. The dominant streamtype upstream from BFR 2 is a B3c channel type with the exception of reaches that have encroachment from road systems. These reaches are usually F3 stream types. The existing conditions are highly altered by the Stimson diversion dam, a large fill along the mill encroaching into the river, sediment deposition created by backwater conditions related to the fill and the dam, and highway encroachments. With Stimson diversion dam and the fill removed, the potential streamtype for the entire reach would be a B3c channel. Like Reach BFR 1, the channel could be reshaped into a narrower channel with a sloping flood prone area adjacent to the channel. Overall valley gradient is about 0.003 ft./ft. over a distance of about 6,500 feet.

The upstream extent of Reach BFR 2 was determined using the FEMA FIRM profiles and a field review intended to document channel depositional features that could be related to backwater effects of the Stimson diversion dam and the channel fill constricting the river just upstream from the dam. Upstream from the Stimson diversion dam, the point where the depositional features start to disappear is approximately the same point where the flood profile gradient begins to steepen (Cross section U on the FEMA profile). Apparently, the backwater effect of



the Stimson diversion dam, in conjunction with the channel constriction just upstream from the dam, affects the river during large floods for approximately 6,500 feet upstream. An actual ending point could not be determined with the limited data available. In addition, other effects make the exact point difficult to determine, such as the constriction of the channel in several places from Highway 200 upstream from the Stimson diversion dam. For the limited purposes of this CRP, a point about 6,500 linear feet upstream from Stimson diversion dam will be used as the upstream terminus of Reach BFR 2.

### **3.0 HYDROLOGY AND FLOOD SERIES ANALYSIS**

This section will summarize the hydrology of the project area and provide an estimation of the bankfull discharge and flood characteristics for the two rivers.

#### **3.1 GENERAL DESCRIPTION**

The watershed area upstream of Milltown dam encompasses 5,984 square miles (3,829,760 acres), with elevations ranging from 3,218 feet at the Milltown dam powerhouse to over 8,000 feet at both the Blackfoot River and Clark Fork River sub-watershed divides. The Clark Fork River watershed is located west of the Continental Divide with most of the headwater streams originating along the Continental Divide. The Blackfoot River sub-watershed has relatively high mean annual precipitation ranging from 16 inches at the confluence with the Clark Fork River to 60 inches at the watershed divide (USDA Soil Conservation Service, 1990). The Clark Fork River sub-watershed has a lower mean annual precipitation ranging from 14 inches near Milltown dam to 50 inches at the divide (USDA Soil Conservation Service, 1990). A majority of the precipitation in both sub-watersheds occurs as snow that typically melts between April and June producing snowmelt runoff dominated hydrographs.

USGS gauging stations provide historical flow information for the Blackfoot River and the Clark Fork River both upstream and downstream of the project area. Discharge on the Blackfoot River is slightly regulated by Nevada Creek Reservoir and is affected by the appropriation of surface water for the irrigation of approximately 20,000 acres. Discharge on the Clark Fork River above Milltown dam is somewhat regulated by the Warm Springs Ponds on Silver Bow Creek near Anaconda and Georgetown Lake on Flint Creek and is affected by the appropriation of surface water for the irrigation of approximately 100,000 acres. Discharge on the Clark Fork River above Milltown dam is heavily regulated with diurnal fluctuations and is affected by the appropriation of surface water for the irrigation of approximately 120,000 acres.

#### **3.2 HYDROGRAPH DISCUSSION**

Mean daily discharge values from the pertinent USGS stream flow gauging stations were reviewed to evaluate the timing, magnitude, and duration of peak and base flow discharges. In addition to providing important data for channel design, this information was used to forecast stream flow conditions that will likely be experienced during the implementation phase of this project.

Based on data available for the periods of record, the Blackfoot River typically flows less than 700 cfs from September through March with baseflow (discharge less than 600 cfs) discharge occurring from mid-December through early February. Discharge typically exceeds 5,000 cfs

from mid-May through mid-June with peak flows occurring in early June. The Clark Fork River at Turah Bridge typically flows less than 1,000 cfs from July through March and experiences baseflow (discharge less than 700 cfs) conditions from early August through early September, and from mid-to-late December. Flows on the Clark Fork River at Turah Bridge typically exceed 2,000 cfs from early May through late June with peak flows occurring in early June. The Clark Fork River above Missoula typically flows less than 2,000 cfs from July into March with baseflow conditions (discharge less than 1,500 cfs) from mid August through early October, and from early December through February. Flows on the Clark Fork River below the confluence typically exceed 8,000 cfs from mid-May through late June with the highest flow typically occurring during the first week of June. Low flow conditions in the Clark Fork River in August and September are related to surface water appropriations and diversions for a variety of beneficial uses.

### **BANKFULL DISCHARGE ANALYSIS**

The bankfull discharge is the most frequently re-occurring flow associated with moving sediment, forming and shaping bars, and maintaining the main morphological characteristics of natural stream channels (Rosgen, 1994). Bankfull discharge is associated with a momentary maximum flow, which, on average, has a recurrence interval of 1.5-1.8 years as determined using a flood frequency analysis (Dunne and Leopold, 1978). WCI performed a detailed analysis to calibrate bankfull discharge for the Blackfoot River and the Clark Fork River upstream and downstream of the confluence with the Blackfoot River. The first analytical method determined bankfull discharges using both past USGS flood frequency analyses and USGS regional equations (Omang, 1992). The second analytical method determined bankfull discharges using historical gage data and applied six different statistical approaches. In most cases, the error factor was less than 15%. The bankfull discharge results are a first estimation and will require further validation during consecutive design phases of this project. The following table summarizes the bankfull discharge for specific reaches in the project area.

| <b>TABLE 1</b><br><b>THE PREDICTED BANKFULL DISCHARGE (CFS), RANGE, AND MARGIN OF ERROR FOR</b><br><b>THE CLARK FORK RIVER (UPSTREAM OF THE CONFLUENCE), BLACKFOOT RIVER</b><br><b>(UPSTREAM OF THE CONFLUENCE), AND THE CLARK FORK RIVER</b><br><b>(DOWNSTREAM OF THE CONFLUENCE).</b> |  |   |  |
|---|--|---|--|
|   | <b>CLARK FORK</b><br><b>RIVER</b><br><b>(UPSTREAM OF</b><br><b>CONFLUENCE)</b> | <b>BLACKFOOT RIVER</b><br><b>(UPSTREAM OF</b><br><b>CONFLUENCE)</b> | <b>CLARK FORK</b><br><b>RIVER</b><br><b>(DOWNSTREAM OF</b><br><b>CONFLUENCE)</b> |
| <b>Bankfull Discharge</b>   | 3,300  | 7,400   | 10,600   |
| <b>Margin of Error</b>  | ± 320  | ± 740   | ± 1,060  |
| <b>Range</b>  | 2,880 – 3,530  | 6,660 – 8,140   | 9,540 – 11,660   |

## **FLOOD SERIES ANALYSIS**

A detailed flood frequency analysis using historical gage data and several statistical distributions was performed to determine discharges associated with selected recurrence intervals. Statistical analyses included normal distribution, log-normal distribution, gumbel distribution, extreme value distribution, and log-Pearson III distribution. Analyses were performed for the four pertinent USGS Gages, including: 1) the Blackfoot River near Bonner (#12340000); 2) the Clark Fork River at Clinton (#12331900); 3) the Clark Fork River at Turah Bridge (#1234550); and 4) the Clark Fork River above Missoula (#12340500). The periods of record for each gage are 68 years, 14 years, 16 years, and 72 years, respectively. The following table summarizes the discharge values produced by applying the statistical method with the highest correlation coefficients for the individual USGS stream flow gages.

| <b>TABLE 2</b>  |  |                      |                      |                       |                       |                       |                        |
|---|--|----------------------|----------------------|-----------------------|-----------------------|-----------------------|------------------------|
| <b>THE PREDICTED DISCHARGE (CFS) FOR SELECTED RECURRENCE INTERVALS USING THE STATISTICAL METHOD WITH THE HIGHEST CORRELATION COEFFICIENT.</b> |  |                      |                      |                       |                       |                       |                        |
| <b>USGS GAGING STATION</b>  | <b>DISCHARGE ASSOCIATED WITH RECURRENCE INTERVAL (CFS)</b> |                      |                      |                       |                       |                       |                        |
|   | <b>Q<sub>1.5</sub></b>                                     | <b>Q<sub>2</sub></b> | <b>Q<sub>5</sub></b> | <b>Q<sub>10</sub></b> | <b>Q<sub>20</sub></b> | <b>Q<sub>50</sub></b> | <b>Q<sub>100</sub></b> |
| <b>Clark Fork-Upstream</b>  | 3,500  | 4,740                | 8,210                | 10,930                | 13,850                | 18,080                | 21,600                 |
| <b>Blackfoot River</b>  | 6,350  | 8,500                | 12,650               | 15,570                | 18,490                | 22,430                | 25,520                 |
| <b>Clark Fork-Downstream</b>  | 11,500   | 14,460               | 22,040               | 27,480                | 32,980                | 40,480                | 46,400                 |

As summarized in Table 2, the predicted bankfull discharges for the Clark Fork at Turah Bridge, the Clark Fork River near Missoula, and the Blackfoot River near Bonner were 3,500, 6,350, and 11,500 cfs, respectively. When compared to the predicted bankfull discharges presented in Table 1, the Q<sub>1.5</sub> estimate is within 15 percent of the predicted bankfull discharge, which further validates the prediction.

## **4.0 CHANNEL DIMENSIONS AND HYDRAULIC ANALYSIS**

This section will predict the preliminary proposed channel dimensions to be used in the conceptual design. Channel design dimensions and meander geometry relationships are presented along with hydraulic calibration of the dimensions.

### **4.1 CHANNEL AND FLOODPLAIN DIMENSIONS**

#### **4.1.1 OVERVIEW**

Natural channel design requires that the active channel be sized to accommodate the bankfull discharge and an adequate vegetated floodplain (or flood prone area) be constructed to convey flood flows of higher magnitude. The geomorphology of this area suggests that a single thread channel of both C (riffle/pool dominant habitat) and B (riffle/step pool dominant habitat) stream types, depending on the slope and degree of entrenchment or width of available floodplain, are appropriate.

Channel design parameters and dimensions include the bankfull discharge, width, mean depth, maximum depth, scour depth, cross-sectional area, and the width:depth ratio. Design dimensions are developed through a rigorous process that includes analog based hydraulic modeling (i.e. HEC-RAS), analytical field calibration (i.e. reference reach surveys), and empirical approaches (i.e. regional curves). For this level of design, a brief field review was conducted to measure existing bankfull widths in nearby undisturbed (“reference”) sections, but no detailed channel surveys or hydraulic modeling of existing conditions was conducted. Channel dimensions for both riffle and pool habitat features have been developed for each reach. The bankfull discharge, depth, channel roughness, and slope all serve to determine the necessary cross-sectional area for a reach. An iterative process of refinement allows for the design channel to produce in-channel shear stresses sufficient to maintain sediment entrainment. Pool dimensions have been tailored to provide deep pool habitat with cover that is critical for over wintering and over summering for large and small fish, including bull trout.

#### 4.1.2 CHANNEL DIMENSIONS

Three sets of channel dimensions for the Clark Fork River have been developed and are summarized in Tables 3 and 4. Detailed cross-section templates for each set of channel dimensions are included in Appendix 3. In the upper portion of the project area upstream of Duck Bridge, slope and floodplain availability allow for a designed C4 stream type with corresponding channel characteristics and dimensions noted in Table 3. From The Duck Bridge downstream to the confluence with the Blackfoot River, the Clark Fork River transitions from a C4 channel type to a B3 type (refer to Section 2.4 for a more detailed discussion on this transition). B3 channel type design dimensions for the Clark Fork River from The Duck Bridge downstream to the confluence with the Blackfoot River are summarized in Table 3.

**TABLE 3: Design dimensions for Reaches CFR3 and CFR4 of the Clark Fork River (upstream of the Duck Bridge).**

| CLARK FORK RIVER (UPSTREAM OF DUCK BRIDGE)<br>BANKFULL CHANNEL DESIGN DIMENSIONS<br>C4 STREAM TYPE |                     |                     |
|--|---------------------|---------------------|
| PARAMETER/FEATURE  | POOL                | RIFFLE              |
| Discharge  | 3,300 cfs           | 3,300 cfs           |
| Width  | 156 ± 10 ft         | 130 ± 10 ft         |
| Mean Depth   | 4.8 ft              | 5.8 ft              |
| Max. Depth   | 14.5 ft             | 7.2 ft              |
| Scour Depth  | 20.3 ft             | 8.7 ft              |
| Cross-Sectional Area   | 860 ft <sup>2</sup> | 750 ft <sup>2</sup> |
| Width/Depth Ratio  | N/A                 | 22.4                |

**TABLE 4: Design dimensions Reach CFR2 of the Clark Fork River  
(upstream of the confluence).**

| CLARK FORK RIVER (UPSTREAM OF CONFLUENCE)<br>BANKFULL CHANNEL DESIGN DIMENSIONS<br>B3 STREAM TYPE |                     |                     |
|---|---------------------|---------------------|
| PARAMETER/FEATURE   | POOL                | RIFFLE              |
| <b>Discharge</b>  | 3,300 cfs           | 3,300 cfs           |
| <b>Width</b>  | 140 ± 10 ft         | 125 ± 10 ft         |
| <b>Mean Depth</b>   | 4.4 ft              | 4.8 ft              |
| <b>Max. Depth</b>   | 12.0 ft             | 6.0 ft              |
| <b>Scour Depth</b>  | 15.4 ft             | 7.7 ft              |
| <b>Cross-Sectional Area</b>   | 690 ft <sup>2</sup> | 600 ft <sup>2</sup> |
| <b>Width/Depth Ratio</b>  | N/A                 | 26.0                |

One set of channel dimensions for the Blackfoot River was developed and is presented in Table 5. These B3 channel type dimensions are suitable for both Reach BFR1 and Reach BFR2 of the Blackfoot River.

**TABLE 5: Design dimensions for Reaches BFR1 and BFR2 of the Blackfoot River.**

| BLACKFOOT RIVER (UPSTREAM OF CONFLUENCE)<br>BANKFULL CHANNEL DESIGN DIMENSIONS<br>B3 STREAM TYPE |                       |                      |
|--|-----------------------|----------------------|
| PARAMETER/FEATURE  | POOL                  | RIFFLE               |
| <b>Discharge</b>   | 7,400 cfs             | 7,400 cfs            |
| <b>Width</b>   | 195 ± 10 ft           | 175 ± 5 ft           |
| <b>Mean Depth</b>  | 6.0 ft                | 6.6 ft               |
| <b>Max. Depth</b>  | 16.5 ft               | 8.6 ft               |
| <b>Scour Depth</b>   | 21.2 ft               | 10.6 ft              |
| <b>Cross-Sectional Area</b>  | 1,335 ft <sup>2</sup> | 1160 ft <sup>2</sup> |
| <b>Width/Depth Ratio</b>   | N/A                   | 26.5                 |

A final set of channel dimensions for the Clark Fork River downstream of the confluence with the Blackfoot River was developed and is summarized in Table 6. The B3 channel type dimensions are suitable for Reach One of the Clark Fork River.

**TABLE 6: Design dimensions for Reach CFR1 of the Clark Fork River  
(downstream of the confluence).**

| CLARK FORK RIVER (DOWNSTREAM OF CONFLUENCE)<br>BANKFULL CHANNEL DESIGN DIMENSIONS<br>B3 STREAM TYPE |                      |                       |
|---|----------------------|-----------------------|
| PARAMETER/FEATURE   | POOL                 | RIFFLE                |
| Discharge   | 10,600 cfs           | 10,600 cfs            |
| Width   | 235 ± 5 ft           | 215 ± 5 ft            |
| Mean Depth  | 8.3 ft               | 9.2 ft                |
| Max. Depth  | 20.2 ft              | 11.5 ft               |
| Scour Depth   | 29.4 ft              | 14.7 ft               |
| Cross-Sectional Area  | 2270 ft <sup>2</sup> | 1,970 ft <sup>2</sup> |
| Width/Depth Ratio   | N/A                  | 23.4                  |

All cross-sectional design parameters for riffle habitats are summarized in Table 7. Riffle sections are compared because most parameters are based on a bankfull width at a stable riffle section and these sections tend to be the most hydraulically consistent. It may be noted that the width, depth and cross sectional area is less for the B3c reach of the CFR 2 than the C4 reach of CFR 4. This decrease in size is due to the increase in gradient for CFR 2, which increases velocity and necessitates a reduction in channel capacity to maintain a channel that just contains the bankfull discharge.

**TABLE 7: Summary table of bankfull channel design dimension  
(riffle habitat features) for all reaches.**

| SUMMARY OF BANKFULL CHANNEL DESIGN DIMENSIONS<br>RIFFLE HABITAT DIMENSIONS |                     |                     |                       |                       |
|--|---------------------|---------------------|-----------------------|-----------------------|
| PARAMETER/FEATURE  | CLARK FORK<br>RIVER | CLARK FORK<br>RIVER | BLACKFOOT<br>RIVER    | CLARK FORK<br>RIVER   |
|  | REACHES<br>CFR3 & 4 | REACH CFR2          | REACHES<br>BFR1 & 2   | REACH CFR1            |
| Stream Type  | C4                  | B3                  | B3                    | B3                    |
| Discharge  | 3,300 cfs           | 3,300 cfs           | 7,400 cfs             | 10,600 cfs            |
| Width  | 130 ± 10 ft         | 125 ± 10 ft         | 175 ± 5 ft            | 215 ± 5 ft            |
| Mean Depth   | 5.8 ft              | 4.8 ft              | 6.6 ft                | 9.2 ft                |
| Max. Depth   | 7.2 ft              | 6.0 ft              | 8.6 ft                | 11.5 ft               |
| Scour Depth  | 8.7 ft              | 7.7 ft              | 10.6 ft               | 14.7 ft               |
| Cross-Sectional Area   | 750 ft <sup>2</sup> | 600 ft <sup>2</sup> | 1,160 ft <sup>2</sup> | 1,970 ft <sup>2</sup> |
| Width/Depth Ratio  | 22.4                | 26.0                | 26.5                  | 23.4                  |



## 4.2 PLAN FORM GEOMETRY

Plan view geometry and characteristics are also a function of the bankfull discharge and the bankfull design width. The most probable channel patterns for the project area reaches were determined from empirical models developed by Leopold et al (1964), Williams (1986), Rosgen (1996), and WCI's reference reach database. Plan view design parameters were calculated for the individual project reaches and are summarized in Table 8. Bankfull channel parameters included the design sinuosity, meander length range, curvature radii, and step frequency. The design belt width, a floodplain characteristic, is also included.

**TABLE 8: Summary table of plan form channel and floodplain design dimension for all reaches.**

| SUMMARY BY REACHES<br>BANKFULL CHANNEL DESIGN DIMENSIONS |                                 |                                 |                                 |                        |
|--|---------------------------------|---------------------------------|---------------------------------|------------------------|
| PARAMETER/FEATURE  | CLARK FORK<br>RIVER             | CLARK FORK<br>RIVER             | BLACKFOOT<br>RIVER              | CLARK FORK<br>RIVER    |
|  | REACHES<br>2, 3 & 4             | REACH 2                         | REACHES<br>1 & 2                | REACH 1                |
| <b>Stream Type</b>                                       | C4                              | B3                              | B3                              | B3                     |
| <b>Design Sinuosity</b>                                  | 1.5                             | 1.3                             | 1.3                             | 1.3                    |
| <b>Meander Length<br/>Range</b>                          | 1,500 ± 250 ft<br>(1,250–1,750) | 1,560 ± 250 ft<br>(1,310–1,810) | 2,100 ± 350 ft<br>(1,750–2,450) |                        |
| <b>Radius of Curvature<br/>Range</b>                     | 455 ± 130 ft<br>(325–585)       | 455 ± 130 ft<br>(325–585)       | 610 ± 175 ft<br>(1,750–2,450)   |                        |
| <b>Step Frequency<br/>Range</b>                          | N.A.                            | 4-5* Wbf<br>(520-650)           | 4-5*Wbf<br>(700-875)            | 4-5*Wbf<br>(860-1,075) |
| <b>Meander width ratio<br/>Belt width Range</b>          | 4-20<br>(520-2,600)             | 2-6<br>(260-780)                | 2-5<br>(350-875)                |                        |

The empirical models provided a range of values for channel pattern attributes rather than specific values for channel pattern. All values will be validated in Phase 2 (refer to Section 5.8). The channel patterns and locations may be adjusted to account for the final condition of the valley bottom following reservoir sediment removal. Where feasible, the new channel will be constructed to incorporate established existing vegetation to provide bank stability and habitat, beneficial characteristics for rehabilitating the constructed reaches.

## 4.3 HYDRAULIC ANALYSIS

WCI performed several different preliminary hydraulic analyses during the development of each set of design dimensions. This analysis focused on three independent techniques. First, hydraulic geometries were developed at the pertinent gage station that provided initial information regarding the relationship of cross-sectional area, width, hydraulic radius, mean depth, and wetted perimeter to the bankfull discharge. This type of relational information was then used and extrapolated to develop the first revision of the design dimensions. WCI then utilized

information from FEMA regarding water surface slopes, predicted bankfull discharge, and the preliminary design dimensions for each reach as input into a hydraulic modeling software called WinXSPro (USDA, 1998). This analysis is one-dimensional (cross-sectional) in nature and was iteratively used to refine the each reach's design dimensions to insure that it had the correct cross-sectional geometry to convey the bankfull discharge. Finally, WCI developed a preliminary two-dimensional hydraulic method using HECRAS (hydraulic modeling software developed by the U.S. Army Corps of Engineers). This analysis was critical in further refining the preliminary channel and floodplain design dimensions to insure that the design channel is capable of conveying the discharge and sediment that the watershed naturally produces. Design dimensions of the active bankfull channel were refined throughout this process to focus on in-channel conveyance of the bankfull discharge. Less interest and effort was placed on developing detailed stage height relationships for large magnitude flood events.

Further analyses will be required during Phase 2 and Phase 3, as further described in Sections 5.8 and 5.9.

## **5.0 PROPOSED RESTORATION STRATEGY AND RECOMMENDATIONS**

### **5.1 COMPARISON OF EPA'S PROPOSED PLAN TO THE CRP**

For the development of this CRP it is assumed that EPA's Proposed Plan for the Milltown Reservoir Sediments Operable Unit will include the following remedial actions, a derivation of the Feasibility Study Alternative 7A2:

1. Sediments from Area I will be removed to an elevation that represents the level of the buried alluvium. These sediments will be removed from the site and transported to a repository west of the reservoir.
2. Area III channel sediments will be left in place out of the 100-year floodplain. The sheet pile used to isolate Area 1 sediments will be removed or left in place and cut off below ground surface.
3. The Milltown dam spillway and radial gate structures will be removed to allow construction of a channel designed to carry the 100-year flood. Other dam structures, the powerhouse, divider block, and north abutment wall will be left in place.
4. Grade control will be established on the Clark Fork River in the area of Duck Bridge and on the Blackfoot River near the interstate 90 overpass.
5. A river channel will be excavated into the alluvium. The channel on the Clark Fork River will be capable of carrying the 100-year flood within it's banks. The streambanks will be a rip-rap type bank throughout the Area 1 and extending through the removed dam. The confluence of the Clark Fork River and Blackfoot River will be established upstream of the present dam location.
6. The floodplain of the Clark Fork River will be backfilled to re-establish a floodplain and proper grade. The floodplain will be re-vegetated with grasses.

EPA's proposed plan includes all of Reach CFR 2 and parts of Reaches CFR 1 and BFR 1. As noted in previous sections, Reaches CFR 1 extends further downstream and BFR 1 extends further upstream. As discussed on Section 2.2 through 2.4, CFR 3 includes that portion of the Clark Fork River that is directly affected by Milltown dam. CFR 4 and BFR 2 are included to extend the CRP to the nearest stable point.

The proposed restoration strategy coordinates with some of these treatments, modifies or enhances other treatments and replaces some treatments altogether to fit the Natural Channel Design (NCD) concept. A brief comparison of the two approaches is provided in the following discussion, identified by the same bullet number as used above. Complete details of the proposed restoration plan are included in the Sections 5.2 through 5.4.

1. This action is assumed to be fully implemented and is unchanged in the CRP.
2. The CRP proposes to remove all sheet piling.
3. The CRP proposes to remove all dam structures, including the powerhouse, divider block, and north abutment wall while re-grading the entire area into channel and floodplain. Because of the historical nature of the powerhouse, it may be appropriate to build a replica of the powerhouse on site out of the floodplain. Parts of the powerhouse, such as the generators, could be relocated on the replica.
4. The CRP proposes grade control throughout all reaches with the use of many different kinds of structures designed to benefit natural channel processes, fish habitat, fish passage, flood plain function, boating and other resource goals. Descriptions of the proposed structures are in Section 5.2 through 5.4. No single, massive grade control structures are planned, as proposed in the EPA proposed remediation plan.
5. The CRP proposes to excavate the new channel into the alluvium, where necessary, but the channel will be designed to carry the bankfull discharge (1.5-year flood), rather than the 100-year flood. The Natural Channel Design concept used in the CRP promotes the design of a channel that can accommodate the normal annual high flow within the active channel. A floodplain or flood prone area is designed adjacent to the active channel to accommodate a whole range of flood flows including the 100-year flood. Stream banks would be stabilized using a much softer approach, using rock and log structures designed to meet the objectives outlined in Section 1.0, specifically, minimal streambank erosion of areas containing significant levels of contamination. No rip-rap or armored banks are proposed in the CRP. The confluence of the two rivers would be established upstream from the present dam location, but would be slightly downstream of the confluence proposed in the EPA proposed plan.
6. The floodplain of the Clark Fork River will be backfilled to the grade necessary to re-establish a floodplain or flood prone area appropriate for the geomorphic setting. This floodplain or flood prone area would be activated during most years to some degree, rather than only above the 100-year flood as in the EPA proposed plan. Revegetation treatments proposed in the CRP are much more aggressive and intensive to promote true restoration of the floodplain and riparian areas in order to meet the established objectives. EPA's proposed plan includes only grasses, with no discussion of how the natural riparian species would re-colonize the site. The CRP augments the planting of grasses

with a full complement riparian, upland and wetland species designed to replace the habitats that occupied the site prior to dam construction. Refer to Section 5.4.5 for a description of all revegetation treatments proposed in the CRP.

The CRP utilizes the natural channel design (NCD) concept, which aims to restore natural channel stability, or dynamic equilibrium, and habitat to impaired streams. When properly applied, NCD methods provide a robust, widely tested, and well-accepted approach to the design of natural channels that successively achieve habitat and geomorphic restoration objectives while functioning during extreme flood events (Schmetterling and Pierce, 1999). NCD is the foundation for developing a naturally stable channel design and meeting habitat restoration objectives. NCD focuses on restoring geomorphic characteristics while incorporating fish habitat structures composed of native materials in natural arrays that better replicate native salmonid habitat as necessary for restoring inland native fish populations. Additional information on NCD can be found in Appendix 9.

## **5.2 PLAN VIEW, LONGITUDINAL PROFILE, CROSS SECTIONS**

All available data sources were used to develop the plan view alignments, longitudinal profiles and cross sections. Data sources included the FEMA FIRM maps (1988), Land and Water Consulting, Inc. cross-section data (1998), aerial photogrammetric base map by Horizons, Inc. (2000), and the Sediment ISOPAC Map (Titan Environment, 1995, geo-referenced by EMC<sup>2</sup> in 2002). All data were geo-referenced to NAD, 1983, and NAVD 1988.

The data was generally adequate for a conceptual level design, but large data gaps existed, particularly in Reaches CFR 3 and 4. The plan view was developed using standard channel and meander geometry dimensions as described in Section 4. The channel plan view is considered conceptual at this point due to very limited data. The detailed plan view alignments can be validated and updated during Phase 2 of the design process.

The longitudinal profile was developed with the objective of keying the proposed floodplain to existing floodplains and vegetated features. Valley gradients were kept as constant as possible to minimize potential problems associated with sudden changes in gradient. The proposed gradient is shown as a water surface profile at bankfull stage and a consistent bed profile that is parallel to the water surface profile. The bed gradient is not intended to illustrate pool, riffle, run and glide habitats, but rather to indicate the elevation of the grade control at any point in the profile. More detailed profiles can be developed during Phase 2 of the design process.

For the Clark Fork River Reaches, the valley gradient is illustrated rather than the stream profile. There is enough uncertainty in the plan view of the proposed C type channel and a high sinuosity so that the profile could vary significantly. For this reason, the valley profile is illustrated with the understanding that the channel gradient can be calculated by dividing the total change in elevation by the total channel length. The Blackfoot River system had much less uncertainty and also a very low sinuosity, so the channel gradient is shown in this case. In other words, there is little difference between the valley profile and the channel profile for the Blackfoot River. Refer to Appendix 7 for displays of the longitudinal profiles.

Cross sections were developed using the template channel geometry and dimensions overlain on the existing land surface or the surface predicted to exist after sediment removal. There is a high level of uncertainty associated with the post-sediment removal land surface, so the channel cross sections are considered conceptual. Floodplains were designed to minimize cuts or fills and to meet the minimum criteria in most cases.

### 5.3 PROPOSED CHANNEL FEATURES, STRUCTURES AND DETAILS

This section will summarize the proposed channel features and quantities. For more detailed estimates of the number of structures, cut and fill volumes and quantities, refer to the cost estimate sheets included in Appendix 6. Most features discussed in this section are displayed on the Plan View Sheets in Appendix 4.

| <b>TABLE 9</b><br><b>PROPOSED CHANNEL AND REACH DIMENSIONS</b> |             |         |         |          |       |           |         |
|--|-------------|---------|---------|----------|-------|-----------|---------|
| CHARACTERISTIC   | REACH       |         |         |          |       |           |         |
|  | BFR-1       | BFR-2   | CFR-1   | CFR-2    |       | CFR-3     | CFR-4   |
| <b>Proposed Stream Type</b>                                    | B3c         | B3c     | B3c     | B3c      | C4    | C4        | C4      |
| <b>Entrenchment</b>  | 1.7         | 2.0     | 1.2     | 3-9      | 3-9   | 9-19      | 4-8     |
| <b>Width/Depth</b>   | 26          | 26      | 23      | 22       | 26    | 22        | 22      |
| <b>Valley Length (ft)</b>                                      | 5650        | 6500    | 5250    | 3850     |       | 7000      | 15400   |
| <b>Stream Length (ft)</b>                                      | 6100        | 7600    | 5500    | 4300     |       | 10400     | 19400   |
| <b>Sinuosity</b>   | 1.1         | 1.2     | 1.04    | 1.1      | 1.3   | 1.48      | 1.3     |
| <b>Stream Gradient (mean)</b>                                  | 0.002-0.005 | 0.002   | 0.002   | 0.005    | 0.004 | 0.0013    | 0.0024  |
| <b>Valley Gradient (mean)</b>                                  | 0.002-0.005 | 0.002   | 0.002   | 0.006    | 0.006 | 0.002     | 0.003   |
| <b>Belt Width (ft)</b>   | 300-350     | 300-350 | 225-700 | 400-1200 |       | 1000-1400 | 500-800 |
| <b>Meander Width Ratio</b>                                     | 2-5         | 2-5     | 1.2     | 2-5      | 4-20  | 4-20      | 4-20    |

#### 5.3.1 CFR 1 AND POWERHOUSE

The proposed channel is a B3<sub>c</sub> channel with a mean gradient of about 0.002 ft./ft. The minimum flood prone width for this channel is about 500 feet compared to a width of about 250 feet available with only the spillway and radial gates removed. The limited width created by removing only the spillway and radial gate necessitates removing all the dam structures, including the powerhouse, divider block and north abutment wall to create an adequate floodplain. If the powerhouse and associated structures were to be left in place, this CRP should not be implemented. In order to secure the physical and biological functions as well as a stable self-maintaining channel, which are objectives of this project, all dam structures must be removed or relocated out of the flood prone area. Specifically, the reasons the powerhouse and associated structures need to be removed are as follows:

- With the powerhouse in place, the limited width of the flood prone area would create a severe constriction, which will cause backwater deposition (excess sediment deposition/aggradation) during even moderate flood events (see Appendix 2, Photo 5 – CFR 1). Plan View Sheet CFR 1 in Appendix 4 and the cross section sheet in Appendix 7 illustrate the approximate floodplain needed for a five-year return interval flood (about 22,000 cfs) without creating backwater deposition. The floodplain width for a five-year return interval flood is about 330 feet (extending about half way through the powerhouse structure).
- A 100-year return interval flood would be about 46,000 cfs, which would require a flood prone width of at least 500 feet to minimize the risk of creating backwater effect. Naturally stable B<sub>3</sub> stream types have an entrenchment ratio of up to 2.2 (flood prone width/ bankfull width) at an elevation two times maximum bankfull depth. With the powerhouse in place, a major flood would create backwater conditions that would bury the entire channel and some of the floodplain with large cobble and small boulder sized bedload sediment.
- Following each major flood, within the area affected by backwater deposition, all structures would be filled with sediment. This would increase the risk that the floodwaters would attempt to flank structures and create new channels.
- Excessive maintenance would be required after even small floods. Maintenance would include channel and floodplain excavation and disposal of the gravel; reconstructing structures; and complete revegetation. The maintenance would add a large cost to the project after each flood, which would continue indefinitely into the future.
- Aquatic habitat would be damaged following flood events as a result of sediment deposition and the subsequent maintenance.
- The constriction would increase velocity during all flood events, which would likely preclude fish migration during that period.
- The constriction and backwater would result in increased flood stage upstream from the powerhouse as well as increased shear stress and scour at the constriction and immediately downstream.
- The sudden expansion downstream from the constriction would create back-eddy erosion on the stream banks downstream from the constriction.

In summary, this CRP is designed to achieve all the objectives outlined in Section 1.0. The design is predicated on the removal of the spillway, powerhouse and all associated structures. Without removing all of the dam structures, the CRP will not be successful, the objectives will not be met and the CRP should not be implemented.

With the powerhouse and north abutment wall removed, the flood prone area on the north side would be filled and graded at the appropriate elevation. Some of the Area III sediments on the



northeast side of the confluence would be needed to grade the bay where the turbines discharge into a floodplain. The island downstream between the Milltown dam and railroad bridge would remain with part of the flows routed through the side channel (less than 30 percent during bankfull conditions). The side channel presents some opportunities for fish habitat and additional recreational experience. Initial calculations suggest that cuts and fills will balance in reach CFR 1.

Downstream from the railroad crossing the side channel converges with the main channel. At this point, the river transitions into a stable F3 type channel. No additional work is proposed at this time between the I-90 bridge (Station 0+00) and Station 28+00 in CFR 1. The railroad bridge has an adequate span to accommodate the channel and flood prone area. A “W” weir or similar structure would need to be designed in Phase 3 to route the flows between the bridge piers to maximize sediment transport efficiency and minimize scour. Details of bridge construction are not known at this time.

Structures proposed in this reach would serve multiple functions: grade control and step pool morphology; bank stabilization; fish habitat complexity and river floating. Because this reach has a step-pool morphology and it is a large river, the structures would be constructed primarily of large rock, but large woody debris and root wads would be incorporated into all structures for habitat. Refer to Section 5.4 for descriptions and illustrations of the proposed structures. The detail sheet in Appendix 5 is an example of how a combination of these structures could be placed in this reach. Proposed structures include “J” Hook vanes, cross vane, single and double wing deflectors, converging roller eddy composites and converging rock clusters. This reach would be completely reshaped in to a steeper overall gradient and flows the channel will be narrower and deeper than the existing conditions. Shear stresses would also be greater on fresh fill material used to construct the channel and banks. Grade control and bank stabilization structures would need to be constructed at the proposed density and frequency to prevent channel down cutting and bank erosion until the natural sorting can take place and the revegetation matures. These structures are designed to allow fish passage upstream and downstream at most flow conditions present when the fish are conditioned to move. Also, river boating opportunities are enhanced with the proposed structures. Rock structures constructed with large rock are appropriate in this geomorphic setting with the south bank occurring on a bedrock outcrop.

### **5.3.2 CFR 2**

As described in Section 2.4, this reach would be constructed to a C4 stream type in the upper half of the reach, transitioning into B3c streamtype for the lower half of the reach. Floodplain widths would also transition from about 1,000 feet wide at the Duck Bridge grade to about 300 feet near the confluence. Stream gradient would range from about 0.004 ft./ft. in the upstream C4 stream type portion to about 0.005 ft./ft. in the lower B3c stream type portion.

Area III sediments with low contaminate concentrations would be graded to fill some of the volume created by the removal Area I sediment. The Area II sediments would be suitable for building floodplains and terraces. Also, since the Duck Bridge grade on the south side creates a constriction on the floodplain during major floods, the fill should be excavated down to floodplain elevation and used as fill for the low areas. Removing the Duck Bridge fill will allow a smooth transition from a wider floodplain to a narrower floodplain that will eliminate rapid

constriction during major floods. After these areas are re-graded, there would be a deficit of about 336,000 cubic yards of fill material that would need to be imported to the Reach. Coarse cobble and gravel should be imported to construct the channel and banks throughout the reach. Excess excavated material from Reach BFR 2 would be ideal for this application because it is clean and has about the correct size composition.

The Area III sediments that currently have relatively high contamination concentrations would be re-graded slightly to provide drainage, and revegetated in place. This area can be described as the existing CFR channel bed, from the existing confluence upstream, to a point opposite Station 80+00 on the proposed channel alignment (Sheet CFR 2 in Appendix 4). This is at about the transition point between the B3c and C4 channel types. The floodplain narrows significantly at this point. Under the remediation plan, the sheet piling that was placed along the north bank of the CFR during the Area I sediment removal would be cut down to just below the finished grade where the high contamination sediment is to remain in place. Under this CRP, all of the sheet piling would be removed. The floodplain would be graded up to this existing elevation at about a 4:1 slope. This area would be higher in elevation than the 500-year flood level and would be isolated from any flood by deep fills and gentle, revegetated slopes. Sheet CFR 2 in Appendix 4 and Example cross-section in Appendix 7 illustrate the treatments in this reach.

Structures proposed for the downstream B3<sub>c</sub> portion of this reach are primarily rock grade control and bank stabilization structures similar to Reach CFR 1. The gradient is steeper in this reach than in either the upstream or downstream reaches. Most of the new channel would be constructed on fresh fill that would not have the natural sorting and grade control of an existing river. To prevent the potential for down cutting and bank erosion that would take place without the structures, fairly high densities of structures are proposed. The detail sheet in Appendix 5 is an example of the types and placements for the proposed structures in CFR 2. The grade control structures are design to create a step-pool morphology and that would allow fish passage upstream and downstream. Also, river boating opportunities are enhanced with the proposed structures. These structures would replace rip-rap and “soft” bank stabilization proposed in the EPA remediation plan.

The upstream C4 portion of the reach would be stabilized with primarily large wood structures such as root wad/log vanes combination structures with rock J hook and large woody debris jam structures. Refer to Section 5.4 for descriptions and illustrations of the proposed structures. These structures are necessary for grade control and bank stabilization until the bed material can become naturally armored and bank vegetation matures. A rock “sill” is proposed at the upstream end of this reach, approximately where the Duck Bridge fill is to be removed to ensure that the newly constructed floodplain remains secure until the vegetation matures. The sill would be constructed at floodplain grade and is basically a trench excavated into the floodplain about three (3) feet deep and filled with large rock. The sill is capped with sod so that it is not visible. This sill could be incorporated into a foundation for a trail or link into proposed bridge abutments.

A footbridge has been proposed in the vicinity of the Duck Bridge grade to connect trails on the north and south sides of the Clark Fork valley. Proposed design criteria for the footbridge are included in Section 5.5. An aggressive revegetation plan is proposed for all reaches following

construction to re-create the riparian and upland habitats that were present prior to dam construction. The proposed revegetation treatments are summarized in Section 5.4.5.

### **5.3.3 CFR 3**

The upstream end of Reach 3 would be reconstructed to a predominantly single thread C4 channel with the existing channels converted to discontinuous wetlands with excavated gravel and soil from the new channel alignment. The channel would be constructed so that the proposed floodplain elevations would match the existing floodplain elevations and established floodplain vegetation. The new channel would have hydraulic and meander geometry appropriate for the geomorphic setting and size of the river. Channel gradient would be about 0.0013 ft./ft. over the total channel length. Whenever possible, the new channel would channel would be constructed to re-activate abandoned oxbows and meanders.

To maintain a consistent grade, the downstream portion of the reach would need to be constructed so that the floodplain would be excavated to a lower elevation. At the downstream end of the reach, the floodplain would be lowered by up to four (4) feet to maintain a relatively consistent stream gradient through the reach. The width of the floodplain would gradually be reduced from greater than 2,000 feet to about 900 feet at the downstream end of the reach. The narrowing of the floodplain would continue downstream into reach CFR 2 to create a smooth transition during large flood events.

The transition to a lower elevation floodplain would be similar to historic conditions and would also greatly reduce the amount of fill required in CFR 2 by lowering the entrance elevation into the reach. Initial calculations indicate that the cuts and fills would balance in the upstream portion of this reach, but the lower portion would result in an excess of about 170,000 cubic yards of fill. Any excess excavated material could be used to fill the floodplains in Reach CFR 2. Any material with contaminant concentrations in excess of desired amounts would be treated to meet the objectives. Whenever possible, existing vegetation would be salvaged and transplanted to the new floodplain elevation. Refer to Section 5.4.5 for the revegetation details.

Any new channel construction would require bank stabilization and grade control until the vegetation can mature. Bank stabilization is necessary not only for proper function of the designed channel, but also especially important in this reach to minimize the amount of contaminated sediments that would be incorporated into the system through bank erosion. Most of the proposed grade and bank stabilization would be accomplished with structures constructed predominantly of wood, such as root wad/log vane combinations with rock “J” hooks and root wad debris jam clusters. Some of the grade control could be accomplished with armored pool tail out structures composed of the largest rock found in the bed (D84-D100 size clast). The number of structures are calculated based on structure size, gradient and stream meander geometry. The grade control structures are designed to match the pool-to-pool spacing common in C4 channels. These structures are designed to function naturally in this geomorphic setting and match the natural stream aesthetics. Fish passage and habitat enhancement are also designed into these structures. Refer to Section 5.4 for more detailed discussion of the structures.

The existing wetlands along the southern portion of this reach would not be graded. It is anticipated that these wetlands and old channels will remain at the low terrace elevation and would be fed by subsurface water from adjacent hill slopes. These wetlands would likely be

intermittent with less surface water supplied from the main channel. The existing stream channels would be filled intermittently, leaving sections of unfilled channel that will be converted to shallow wetlands. These wetlands would receive water during flood events and when the water table was higher than the bottom elevation of the old channels. To minimize the potential for colonization by undesirable non-native fish species, these wetlands would remain isolated.

#### **5.3.4 CFR 4**

This reach would be converted from a braided D4 channel with intermittent F4 reaches to a C4 channel in the same manner as the upstream end of Reach CFR 3, with the new channel floodplain at the same elevation as the existing floodplain features. Like Reach CFR 3, the existing channels would be filled intermittently, or plugged, with excavated material from the new channel locations. Initial calculations indicate that cuts and fills would balance throughout this reach.

The average stream gradient through this reach would be about 0.002 ft./ft. Proposed structures in this reach would be primarily constructed of large wood similar to the upper end of Reach 3. The same types of structures would be constructed in similar locations. The purpose of the structures is for bank stabilization and grade control until natural processes can take over. The number of structures was calculated based on a representative reach of about 2,000 feet of channel where structures were designed in at the appropriate spacing and intervals. The density of structures was extrapolated to the remainder of the Reach. Structure spacing is variable depending on meander geometry, structure type and the pool-to-pool spacing appropriate for the reach.

There would be a short reach of B3c channel constructed through the Turah Bridge section and a rock “W” weir structure constructed at the bridge to effectively transport water and sediment through the bridge section. Refer to Section 5.4 for descriptions and examples of structures.

#### **5.3.5 BFR 1**

This reach would be converted from an F4 channel with backwater conditions to a B3c channel with step pool morphology and a narrow, well-vegetated flood prone area. This would be accomplished by reshaping the existing bed material to narrow and deepen the thalweg and grading excess material up to form a sloping flood prone area. Upstream of the Highway 200 Bridge the gradient is about 0.002 ft./ft. The gradient would steepen to about 0.005 ft./ft. downstream of the Highway 200 Bridge. Initial calculations indicate that cuts and fills balance in this reach.

There are two abandoned piers in the river at the old Highway 200 Bridge crossing that need to be removed to improve channel stability. Most of the bridge spans are adequate to span the active channel and flood prone area, but the railroad bridge is skewed enough to reduce the effective capacity to pass flood flows. A series of rock “W” weirs (one weir at each bridge) would be necessary to split the active channel around the piers while maintaining hydraulic function. These “W” weirs also prevent scour around piers and will pass fish effectively. River boating rafters also tend to enjoy the hydraulic conditions promoted by “W” weirs. Section 5.4 includes details and examples of proposed structures. Refer to Section 5.4.6 for a more detailed discussion of the bridge recommendations.

Other channel structures would be similar to those on the CFR reaches 1 and 2, with rock steps constructed to stabilize the grade and promote fish passage as well as river boating. The detail sheet in Appendix 5 is an example of how a combination of these structures could be placed in this reach.

### **5.3.6 BFR 2**

As discussed in previous sections, the key to restoration in this reach is to remove the Stimson diversion dam and the fill that is encroaching into the river just upstream from the dam. Without removing both features, there is limited opportunity to eliminate the backwater conditions and sediment deposition that has occurred upstream. This constriction, along with the Stimson diversion dam creates a backwater condition that causes sediment deposition and aggradation to occur for at least 6,500 feet upstream. Within the fill that is constricting the river, Stimson diversion dam has a small lagoon and a building of unknown purpose. The building may need to be replaced at some other location. This and removal of the fill would require landowner cooperation and approval.

Also, as noted previously, the Stimson diversion dam is in poor condition and following removal of Milltown dam, would become a fish barrier and should be removed. This reach would be converted from B3c channel with a high width:depth (w:d) ratio and an F4 channel in places to a B3c channel with a lower w:d ratio and a narrow, well vegetated flood prone area. Much of the deposited sediment can be reshaped to create the appropriate channel and flood plain dimensions, but an excess of about 277,000 cubic yards of sediment should be removed and possibly exported to CFR 2. Some of this material is located at the channel constriction and immediately upstream. The clean gravel and cobble sediment would be ideal for the steeper B channel reach of CFR 2. If the material were not exported to CFR 2, there would be additional costs associated with transportation and disposal.

The abandoned railroad bridge piers at about Station 88+00 should also be removed to improve sediment transport and channel stability in this reach. Structures proposed for this reach would be similar to reach BFR 1 and would be constructed primarily of large rock to stabilize the grade and promote fish passage as well as river boating. The detail sheet in Appendix 5 is an example of how a combination of these structures could be placed in this reach. These structures would be consistent with the morphology of the BFR in this canyon reach.

## **5.4 CHANNEL CONSTRUCTION AND RESTORATION TECHNIQUES**

### **5.4.1 CHANNEL CONSTRUCTION**

The CFR and BFR channels would be constructed to the proper cross-section dimensions, planforms, and profiles in order to convey the flows and transport the sediment made available by the watershed. The restored channels would be designed to minimize near-term lateral channel migration while allowing long-term channel adjustment within the respective floodplains. The proposed channel alignments include constructing new channel reaches and modifying existing channel sections. Reconstructing the channels in the project area will improve the amount of fish habitat in the project area, increase the amount of river-floodplain edge, and reduce the energy gradient. The combination of bank stabilization and grade control

structures will limit bank erosion in areas with contaminated sediments left in place to slow erosion rates over time. All structures ultimately rely on an aggressive revegetation plan that would result in a vigorous, dense riparian community that would promote long-term bank stability and floodplain stability.

Natural channel design techniques would be employed and include constructing a two-stage channel to accommodate the predicted hydrograph conditions. A two-stage channel includes a bankfull channel to convey the average annual flood and sediment (bankfull flow) and a floodplain designed to accommodate flows of greater magnitude, including the 100-year flood. Channel-floodplain interaction would reduce in-channel water velocities, shear stress, and bank erosion. Constructed floodplains would serve to moderate flood peaks, store fine sediment, and increase late-season base flows in the respective project reaches.

For new channel reaches, the channel would be built in conjunction with the new floodplain construction following removal and disposal of the polluted sediments. In modified channel reaches where new channel excavation is not necessary, the channel cross-section dimensions, plan form and profile would be shaped to the appropriate design dimensions. The designed channel pattern will minimize backwater macrohabitats that provide preferred habitat for introduced northern pike.

Bank stabilization, grade control, step-pool, and fish habitat structures would be constructed using native materials and would be designed to mimic naturally occurring habitat arrays found in stable stream reaches (Table 10). Rootwads, large woody debris jams, and vegetation would be used for bank stabilization. Grade control structures including cross-vanes, “W” weirs, rock and log straight vanes, and rock and log “J” hook vanes would also provide valuable bank protection. These structures are designed work in concert to provide a complete array of habitat features in a channel system. For example, a log “J” hook vanes might be designed in proximity to a large woody debris jam to provide all the habitat components in a relatively short distance. Higher gradient B stream type reaches on the lower reaches of the Blackfoot and Clark Fork Rivers would be constructed with additional grade control structures designed as low stage steps to create step-pool morphology, including single and double wing deflectors, convergent roller structures, and convergent rock clusters. Descriptions of these structures are included in the following sections.

The proposed structures would be constructed to maximize fish habitat complexity while providing for upstream and downstream fish passage for all native and coldwater fish species. Structures promote flow convergence to increase water depths and diversify channel hydraulics during low flow periods. Flow convergence will also maintain sediment transport competency and pool scour during elevated flows. Deeper pools typically sustain greater numbers of individuals and species of fish compared to shallow pools with less habitat complexity. Large woody debris is also incorporated into structure design to increase fish habitat diversity. The proposed grade control structures are favored by the river boaters to enhance diversity and recreational opportunity. The structures are also designed to mimic natural structures to fit in with the geomorphic setting, thus enhancing aesthetics.



The selected structures have been successfully employed in streams throughout Montana, Idaho, Utah, Oregon, Washington, and Colorado. Structures are sized on a site-specific basis in accordance with the bankfull channel dimensions and the bankfull discharge. Results from project monitoring programs suggest the benefits of the proposed structures to both fisheries and channel stability (WCI *unpublished data*; Schmetterling and Pierce 1999).

| <b>TABLE 10</b><br><b>PROPOSED FISH HABITAT, GRADE CONTROL, BANK STABILIZATION, RIVER BOATING</b><br><b>STRUCTURES AND DERIVED BENEFITS TO FISH.</b> |  |  |   |
|--|--|--|---|
| <b>STRUCTURE</b>   | <b>MATERIALS</b>                         | <b>PURPOSE</b>   | <b>BENEFITS TO FISH</b>   |
| <b>Rootwad<br/>Revetments</b>  | Logs and<br>Rootwads                     | Dissipate energy directed<br>at stream bank, fish<br>habitat                             | Overhead cover, insect<br>production, interstices<br>for YOY and juvenile<br>fish                                 |
| <b>Large Woody<br/>Debris Jams</b>   | Logs, rootwads,<br>small woody<br>debris | Dissipate energy, provide<br>bank protection   | Overhead cover, flow<br>break, debris collector,<br>diverse habitat   |
| <b>Straight and “J”<br/>Hook Vanes</b>   | Logs and Rock                            | Reduce near bank shear<br>stress, enhance channel<br>margin complexity,<br>grade control | Create deep pool<br>habitat critical cover for<br>adult over wintering<br>and summer refuge                       |
| <b>Cross-vanes</b>   | Rock                                     | Grade control and scour<br>pool formation  | Create deep pool<br>habitat and sort gravel<br>for spawning   |
| <b>“W” weirs</b>   | Rock                                     | Grade control and scour<br>pool formation  | Create deep pool<br>habitat and sort gravel<br>for spawning   |
| <b>Vegetation<br/>Transplants</b>  | Vegetation                               | Provide long-term bank<br>stability, organic material<br>source, and stream<br>shading   | Overhead natural cover,<br>stabilize banks, insect<br>production, and<br>increased bank and<br>habitat complexity |

#### **5.4.2 BANK STABILIZATION STRUCTURES**

Bank stabilization structures are necessary for maintaining bank integrity on restored stream reaches until planted vegetation is capable of providing natural bank stabilization. Structures are expected to last for a limited period of time until vegetation provides bank stability in perpetuity. Bank stabilization structures also serve to diversify available fish habitat. Prescribed structures provide overhead cover, flow path complexity, interstitial hiding spaces, and visual separation for fish. Species and age-classes typically segregate according to these microhabitat attributes to reduce inter-size-classes and inter-species interactions. In the Reaches CFR 3 and 4, large wood based structures would be the dominant bank stabilization structures. These structures include rootwad/log vane “J” hook combinations, rootwad composites and large woody debris jams. Constructed with whole cottonwoods, conifers and other native riparian species, structures would emulate naturally occurring habitat arrays. Materials would project varying distances from the bank to deflect scouring eddies away from the bank as well as to diversify fish habitat around the structures. The following section outlines the prescribed structures.

##### **ROOTWAD REVETMENTS**

The purpose of bank placed rootwads is to dissipate water velocities and shear stress in the near-bank region until dense riparian vegetation becomes established. A secondary function and benefit of these structures is the diverse fish habitat that is created. Single rootwad structures would consist of a footer log, anchor rocks, and rootwad. Spacing between rootwads would depend on their position relative to other structures. Rootwads would often be used to complement other structures to increase the amount of bank protection provided by the complementary structure. Each rootwad revetment would have two to four mature willow transplants with attached root masses placed around the point of streambank intersection. Additional plantings would also be completed to improve the long-term natural bank stability. Complementary woody debris would be added to the rootwad revetments to increase fish habitat and bank protection.

##### **LARGE WOODY DEBRIS JAMS**

Large woody debris jams are constructed to mimic naturally occurring woody jams that typically form in the lower 1/3<sup>rd</sup> of meander arcs. Natural jams form over time as high water events overtop the lower portion of the meander, depositing wood on the floodplain. Large wood traps smaller materials, increasing the volume of the jam. Jams create diverse aquatic and overhead habitat for fish, riparian habitat for mammals, and perches for birds. Sizable jams provide bank protection and may create protected growing areas for vegetation.

Constructed woody debris jams are built with several large trees, various sizes of rootwads, small diameter woody material, and large anchor rocks. The large trees are tied into the bank and anchored with large rocks. Other woody material is interlaced among the large key trees to create a diverse array of woody material. Several rootwads and logs are extended out into the channel to diversify the local aquatic environment. Overtime the jams are expected to grow in size as the jam captures other woody debris transported during high water.

### 5.4.3 GRADE CONTROL STRUCTURES

Various grade control structures are prescribed for the restoration project. Grade control structure types and locations would vary according to specific project reaches and project goals. For example, the upstream part of the Reach CFR 2 would include cross-vanes and “J” hook vanes using a combination of large woody debris and large rock. Other structures that would provide river boating opportunities in addition to grade control would be constructed in the downstream B stream type reaches planned for the lower Clark Fork and Blackfoot River segments. Structures will effectively address bed stability concerns and provide enhanced river boating recreation opportunities where appropriate.

The grade control structures maintain the designed channel profile elevations in addition to addressing fish passage and habitat needs. Fish passage concerns are addressed by the design of the prescribed grade control structures. Each structure typically concentrates flows to the thalweg, or deepest portion of the channel. Focusing flows in this manner sustains a deeper low flow water column providing better connectivity during late season base flows.

Structures are also designed to improve flow convergence and sediment transport during high flows. Vane arm gradient and angle from the bank affect the hydraulic head the structures create. A steeper vane arm gradient results in greater hydraulic acceleration over the structure and into the pool created by the structure. This acceleration is necessary for maintaining sediment transport through the pool and subsequently, the depth of the pool. The vane arm gradient and arm length also affect the degree of bank protection created by the grade control structure. A longer, flatter vane arm protects a greater bank distance than a short, steep vane arm.

Rootwads and other large woody debris are typically incorporated into the grade control structure to increase the habitat diversity in the pool. Woody materials are anchored in between or below the vane arms. Material positioning influences vane hydraulics and pool scour, creating a range of aquatic habitats in the project area.

The designed structures would allow for fish passage. Fish passage is typically a concern during base flows when portions of the stream may become disconnected if the streambed is too wide and the water too shallow. Each grade control structure would be designed to have no more than 0.5 ft. to 1.0 ft. of drop (water surface from the structure throat to the water surface downstream) during base flow conditions. Gaps between structure rocks would also allow fish passage from the pool downstream, upstream through the structure. During the majority of the hydrograph, water depths over the vane structures would be sufficient for all species and most age classes to navigate the structures. Fish have been observed inhabiting feeding positions on the downstream sides of vane throats where the flow is focused. During high flows, fish will likely seek refuge in the deep, complex pools. Although the water accelerates over the vane structure, water velocities should not exceed the burst swim speeds of most fish species given the short distance of accelerated velocities.

The hydraulic drop created by the structures also appears to attract spawning salmonids. The hydraulic formed by the vertical distance between the upstream water surface and the downstream water surface increases the flow water through the gravel on the upstream side of

the vane arms. Pool tailouts downstream of the structures are also attractive spawning areas for trout. The combination of optimal gravel sizes, the short distance to deep water, and enhanced inter-gravel flow make pool tailouts downstream from grade control structures optimal spawning areas for salmonids.

### **LOG AND ROCK STRAIGHT VANES**

Straight vanes are built as log or rock vanes. These structures tie into the bank at approximately the bankfull elevation and intersect the channel bed at a point upstream. The slope and length of the vane are determined according to the local channel conditions and purpose of the structure (i.e. bank stabilization versus habitat creation). Straight vanes function by deflecting the high velocity thalweg away from the streambank thereby decreasing the near-bank shear stress. Log vanes are generally preferred over rock vanes as log vanes are less costly (in terms of materials and construction time) and are more natural in appearance. Rock vanes are typically used if large logs are not available or when the long-term stabilization of the channel at the specific location is a necessity.

### **LOG AND ROCK “J” HOOK VANES**

“J” hook vanes are similar to straight vanes except that a log or rock “J” hook is added to the straight vane. The “J” hook concentrates the thalweg more than the straight vane. “J” hooks are typically preferred for this reason. While providing protection for the constructed streambank bank and channel, this structure also allows for efficient transport of bedload and suspended sediment. “J” hook vanes provide grade control and are also used to help maintain extended pool lengths in meanders. Footer rocks are placed below the predicted scour depth to prevent undermining of the structure during high flows. Logs of sufficient size may be used in place of large rock where possible. Log vanes are typically less expensive and easier to install than rock vanes, though they are less permanent than rock structures.

### **ROCK CROSS-VANES**

Cross vanes provide long-term grade control in reconstructed stream channels. Natural channels maintain grade control through undulations in the bed profile (riffle-pool sequences). It is necessary to include some sort of grade control in reconstructed channels due to the non-sorted nature of channel material (gravel, cobble, and sand) following construction. The streambed is unarmored following construction. Cross-vanes would be built according to design channel dimensions and include footer rocks to prevent undermining of the structure during high flows. Constructed scour pools below the cross vane structure will enhance fish habitat and create pools for over-wintering of the resident fishery.

### **ROCK “W” WEIRS**

The design of the “W” weir is similar to the cross-vane in that both sides are vanes directed from the approximate bankfull elevation upstream to a point where the vane intersects the channel bed. The “W” weir divides the river into fourths with the vane arms intersecting the bed at  $\frac{1}{4}$  and  $\frac{3}{4}$ s of the channel width (Rosgen 2001). The center portion of the structure rises in the downstream direction to form a “W” looking from upstream to downstream. The multiple vane arms and center structure increase the number of flows paths, diversifying aquatic habitat around

the structure. “W” weirs maintain deep pools in a similar manner to the aforementioned vanes and cross-vane.

### **COBBLE PATCHES**

Natural stream channels sort and transport bed material in a manner that provides for natural grade control. In some areas of the project, channel materials would be sorted during construction to generate material ranging from the  $D_{84}$  –  $D_{100}$  of the channel bed material (the largest material that is generally not transported). Additional materials may be imported to the project site depending on the availability of on-site materials. These materials would be placed in the designed bed profile to provide grade control at pool tailouts. Cobble patches may also be used in lieu of cross-vanes where additional grade control is not necessary.

| <b>TABLE 11</b><br><b>PROPOSED STRUCTURES DESIGNED TO PROVIDE GRADE CONTROL AND STEP POOL MORPHOLOGY ON THE LOWER CLARK FORK AND BLACKFOOT RIVERS. ALSO FISHERIES BENEFITS ARE INCLUDED.</b> |                                |  |  |
|--|--------------------------------|--|--|
| <b>STRUCTURE</b>   | <b>MATERIALS</b>               | <b>BOATING BENEFIT</b>   | <b>FISHERIES BENEFIT</b>   |
| <b>Converging Rock Clusters</b>  | Rock                           | Diversify flow paths and create complex currents   | Diverse flow paths   |
| <b>Converging Roller Eddy with Rock Vane</b>   | Rock                           | Diversify flow paths and create complex currents, create eddies, deflect thalweg to center channel | Diverse flow paths and backwater resting areas                     |
| <b>Converging Roller Eddy with Rootwad</b>   | Rock                           | Diversify flow paths and create complex currents, create eddies, rootwad bank protection           | Diverse flow paths and backwater resting areas                     |
| <b>Double Wing Deflectors</b>  | Rock with cobble fill material | Flow acceleration and eddy backwater creation  | Diverse flow paths, deep pool habitat, and backwater resting areas |
| <b>Single Wing Deflector</b>   | Rock with cobble fill material | Flow acceleration, complex currents, and eddy creation   | Diverse flow paths, deep pool habitat, and backwater resting areas |
| <b>Random Rock Cover</b>   | Rock                           | Diversify flow paths and create complex currents   | Diverse flow paths   |

#### **5.4.4 ADDITIONAL GRADE CONTROL STRUCTURES**

Mr. Dave Rosgen, P.H. has developed a suite of six structures that create the step-pool effect on larger B type stream systems to stabilize the streambed and dissipate energy. These structures also produce dynamic hydraulics preferred by river boaters (Table 11). These structures are planned for the higher gradient B stream type sections of the lower Clark Fork and Blackfoot Rivers (CFR 1, CFR 2 and BFR 1) where the channel profiles are somewhat steeper, the valleys narrower, and the channel pattern is slightly straighter. The combination of these conditions would allow a channel design that maintains channel and bed stability, sediment transport, flow conveyance, fish habitat and passage, as well as recreational boating opportunities. The prescribed structures would require large rock and woody debris similar to the aforementioned grade control and bank stabilization structures.

##### **CONVERGING ROCK CLUSTERS**

This structure is comprised of multiple boulder clusters that create diverse flow paths. The structure emulates a series of natural rock outcroppings. Fish habitat would be enhanced by the structures and fish passage would not be affected.

##### **CONVERGING ROLLER EDDY WITH ROCK VANE**

The structure is built with at least two rock downstream-facing offsetting vane arms. The arms deflect the flow back and forth and create eddy backwaters on the downstream side of each arm. A standard rock cross vane is positioned downstream of the rock arms. The vane deflects the thalweg back towards the middle of the channel. The structure would allow fish passage at all flow levels.

##### **CONVERGING ROLLER EDDY WITH ROOTWAD**

This structure performs similarly to the aforementioned structure except that the rock vane is replaced with a large rootwad. The rootwad creates local scour and enhanced fish habitat. The structure would allow fish passage at all flow levels.

##### **DOUBLE WING DEFLECTORS**

The double wing deflectors are placed across from each other on the channel margins. The structures are built with large rock in-filled with finer material. The double wing deflectors concentrate the flow to the middle of the channel with a subsequent acceleration of water between the narrowed channel. The elevated water velocities increase the shear stress and scour potential. A large deep pool is typically maintained downstream of the double wing deflectors. The pool would provide fish habitat and would allow fish passage at all flow levels.

##### **SINGLE WING DEFLECTORS**

Single wing deflectors are offset from each other in a reach of the channel. The current deflects back and forth across the channel between the deflectors. The structures are built with large rock in-filled with finer material. The deflectors concentrate the flow to the middle of the channel with a subsequent acceleration of water between the narrowed channel. The elevated water

velocities increase the shear stress and scour potential. A large deep pool is typically maintained downstream of the double wing deflectors. The pool would provide fish habitat, and the structure would allow fish passage at all flow levels. Large eddy backwaters form on the downstream sides of the deflectors, providing resting areas for both boaters and fish.

### **RANDOM ROCK COVER**

Similar to the converging boulder clusters, the random rock cover diversifies the channel and flow paths. Boulder clusters offer obstacles for boaters and create variable currents for fish. The structures are expected to provide diverse fish habitat without affecting fish passage.

In summary, the proposed channel construction and prescribed structures are designed to emulate natural systems. The designed two-stage channels would be constructed according to the geomorphic setting, valley type, infrastructure considerations, and recreation objectives. The designed channels will convey the flows and transport the sediment made available by the Blackfoot River and Clark Fork River watersheds. The bankfull channel will convey approximately the 1.5-year to 1.8-year events while larger flows will access the adjacent floodplain. Bank stabilization, grade control, and river boating structures would benefit the resident and migratory fisheries by providing local habitat and reconnecting migration routes currently severed by Milltown dam. The prescribed structures would not impede upstream or downstream fish migration for the targeted native and coldwater sport fish species.

### **5.4.5 SUMMARY OF RE-VEGETATION PLAN**

The proposed EPA's remediation plan proposes to revegetated disturbed areas with only grasses. To restore the area to a condition similar to pre-dam construction, with all riparian, upland and wetland components functioning in concert, the remediation plan must be supplemented with an aggressive revegetation plan. The importance of a practical and cost effective revegetation plan and the diligent implementation of that plan cannot be overstated nor over-emphasized. The revegetation activities will be key to the success of the overall project and ultimately meeting the objectives established for this CRP. Natural channel design concepts rely on effective revegetation and existing vegetation to provide long-term bank stability, provide energy dissipation and sediment storage on floodplains, provide shade and long-term woody debris recruitment for aquatic habitat and desired aesthetics.

By design, this revegetation plan is conceptual in nature and provides the foundation for a comprehensive, site-specific plan and prescriptions that would be developed once the overall stream restoration project design is finalized. The treatments, techniques and plant materials are described in general terms and apply to broad geomorphic areas.

This revegetation plan was developed to meet multiple objectives including:

- ◆ Re-establishment of a native plant community;
- ◆ Mitigate surface erosion and associated off-site impacts;
- ◆ Restore a healthy, diverse and viable edaphic (soil) environment;
- ◆ Provide for slope and bank stability while minimizing maintenance;

- Re-establish/enhance terrestrial, riparian and aquatic habitat for dependent species;
- Inhibit the establishment of undesirable plant species including noxious weeds; and
- Post-project visuals and esthetics.

This revegetation plan initiates the processes that provide for a diverse, resilient and self-sustaining native plant communities and ecosystems. No revegetation plan is capable of precisely replicating the pre-disturbance native plant communities. Depending on the existing vegetation and the successional stage of the plant community it may not be practical, desirable or even possible to do so. This plan “jump-starts” the recovery of the complex ecologic interactions and reintroduces biological diversity to the project area following restoration activities.

Under this CRP, plant densities and species would be site specific for each of the following treatment areas:

- Stream banks: All stream banks would receive some level of revegetation. Banks along straight reaches and along the “inside” banks of meanders would be treated but to a lesser degree than the higher energy banks. The “outside” banks of meanders require a more rigorous revegetation treatment due to their exposure to high energy and shear stresses during period of high stream flows;
- Abandoned channels: Those sections of active channel that would no longer exist following channel realignment;
- Floodplain: Includes that area outside the active channel that is inundated during flood flows;
- Wetlands: This includes areas of standing water in abandoned channels that are retained after construction of the new channel. They would be converted into a wetland ecosystem with water depths less than four feet;
- Terraces and Uplands: These are the xeric or drier areas at a higher elevation than the adjacent floodplain;
- Other disturbed sites are areas that are disturbed as a result of construction activity such as access routes, borrow sites, etc.; and
- Existing riprap placed along banks during previous efforts to stabilize the stream banks. Vegetation will increase bank stability, provide habitat and improve esthetics.

These geomorphic categories will help ensure that areas of different moisture regimes would be planted with appropriate species thus increasing the survival rate throughout the project area. Following is a brief summary of the re-vegetation plan.

### **WOODY VEGETATION:**

Trees and shrubs used at the Milltown site would be containerized native plants with an established root system. The plants would be grown in a 3-inch diameter by 14-inch long (minimum) up to 36-inch long container. Wetland species would be grown in six cubic inch containers. Cuttings would be limited to native willow species harvested from on-site and/or adjacent areas. They would average 40 inches in length. Cuttings would be planted so the basal



end is submerged in or very near groundwater for the majority of the year, this would increase their survival rate.

An expandable stinger or a ripper-type attachment would be used to install plants. Photographs of the planting equipment and projects where this technology has been used are in Appendix 10. Prior use of this technology has resulted in increased survivability at harsh sites and is particularly suited to Montana as many areas are moisture limited for the majority of the year. This equipment is capable of consistently getting plants and cuttings deep into the soil where there is more available moisture than conventional means. This method relies on fewer laborers, decreased logistics, and additional costs associated with large planting crews. In addition, containerized plants would be inoculated with a diversity of beneficial soil microbes to improve tree and shrub vigor and increase survival rates.

### **GRASS SEED**

The revegetation effort would also include three to four native seed mixes that would be specific to landform and edaphic conditions. A quality organic fertilizer would be applied to all disturbed areas to increase initial vigor of grass establishment. Disturbed soils would be inoculated with a diversity of beneficial soil microbes to further stimulate vegetation. A quality wood-fiber mulch with tackifier and/or straw would be applied on the surface of disturbed areas to help retain soil moisture, lower surface temperatures and control on-site erosion. Hydro mulching is the preferred application method for seeding this project. Since the hydro mulching process seeds, fertilizes and mulches in one step, it is more time effective than other methods of seeding grasses that may require up to three different passes with a machine or laborer.

### **EROSION CONTROL:**

In the majority of the Milltown project area, mulching/hydro mulching would suffice for erosion control needs. Areas that are sloped and may erode would be treated more aggressively to alleviate soil losses. Control measures would include: erosion control blanket, straw, either spread or use the bale whole, and soil tackifying agents as deemed necessary.

## **5.5 BRIDGE RECOMMENDATIONS**

Existing bridges in the project area were evaluated to determine the potential limitations posed on the conceptual restoration plan. The seven bridges in the project area are the Interstate 90 East Bridge, the Interstate 90 West Bridge, the Burlington Northern Railroad Bridge, the State Highway 200 Bridge the old State Highway 200 Bridge (foot travel only), the County Road Bridge at Turah and the railroad bridge downstream from Milltown dam. The first five of these structures span the Blackfoot River in Reach BFR1, while the Turah Bridge is in Reach CFR 4. The railroad bridge downstream from Milltown dam is in Reach CFR 1. Plans were obtained for the Interstate 90 Bridges only. Plans for the other bridges could be acquired and reviewed as part of Phase 2. A brief field review of the bridges was conducted to photograph the structures, measure span lengths and identify pier locations.

Due to the existing over-widened condition of the Blackfoot River, all five bridges could adequately span the proposed minimum 245-foot floodplain width of the Blackfoot River without creating a backwater affect. In addition, adequate freeboard is available for all five

bridges during a 100-year flood event. However, each bridge contains one or more piers that would likely fall within the proposed bankfull channel. Piers located in the bankfull channel could be subjected to scour and debris accumulation during ice flows or flood events. For this reason, a scour and ice flow analysis is proposed as part of Phase 2.

The Turah Bridge appears to have an adequate span for the upper Clark Fork, but channel changes and modifications upstream have resulted in an over-widened and unstable braided condition. There is one pier in the active channel presently.

The railroad bridge in CFR 1 has an adequate span to accommodate the channel and flood prone area. A “W” weir or similar structure would need to be designed in Phase 3 to route the flows between the bridge piers to maximize sediment transport efficiency and minimize scour. Details of bridge construction are not known at this time.

Ideally, bridge piers should be located outside of the bankfull channel. Since modifications to the bridge structures are not part of the scope of this project, other alternatives were explored. To mitigate the possible effects of pier scour, hydraulic structures such as “W” weirs are recommended and included in the conceptual restoration plan. Refer to the plan view alignment sheets for the proposed locations of these structures. “W” weirs are designed to split the flow around a pier thus creating an area of lower shear stress and reduced scour at the pier. Moreover, “W” weirs provide grade control and habitat complexity. In addition to installing hydraulic structures to mitigate pier scour, it is recommended that any abandoned piers or abutments within the bankfull channel be removed. The old State Highway 200 Bridge contains two abandoned piers that should be removed to increase the efficiency of the proposed channel and decrease unnecessary pier scour.



**Photo 5.1**

The Old Highway 200 Bridge

(Note the two abandoned piers that are recommended for removal.)

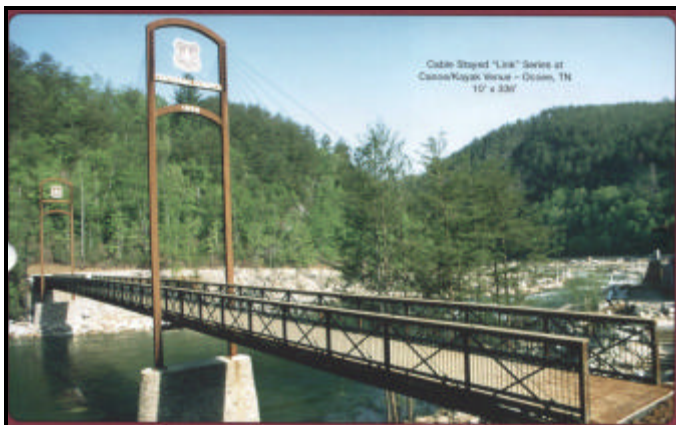
To account for the change in channel gradient that will be caused by removal of the dam, the longitudinal bed profile of the Blackfoot River may have to be adjusted in the vicinity of the five bridges. Due to the limited available information, it was difficult to determine the exact change in bed elevation that would be required. However, it is estimated that the change in bed elevation could be between one and three feet at the bridge locations. Regardless, future proposed bridge scours studies identified in Phase 2 would be required to determine pier foundation depths and, if necessary, limit the change in bed elevation at the pier locations.



**Photo 5.2**  
Example of a “W” weir

In addition to examining existing bridges, efforts were made to identify a potential location for a new pedestrian bridge within the project area. It is assumed that this bridge would be used for non-motorized traffic, such as pedestrians and cyclists. One potential location is the site of the old Duck Bridge (refer to Plan view sheet CFR 2 in Appendix 4). Due to encroachment on the floodplain, the old approach embankments associated with this bridge have been recommended for removal. A new pedestrian bridge should be designed to span the bankfull width of the Clark Fork (130 ft.) at this location to minimize disruption of the flows and sediment transport in the active channel. The bridge piers should be outside the active channel and there should be some floodplain available within the bridge span. This will greatly reduce the risk of scour and adverse affects on the channel and recreational boating. These criteria would result in a minimum bridge span of approximately 170 feet. Since the floodplain at this location is approximately 800 foot in width, the pathway leading to the bridge could be set at floodplain grade, while the bridge and its approaches could be set at least three (3) feet above the 100-year flood elevation to allow clearance for debris during floods.

Several options are available for bridge types. It is estimated that costs could be between \$200,000 and \$400,000 for a pre-fabricated pedestrian bridge. Please refer to the detail sheet in Appendix 7 for a conceptual cross section of the proposed pedestrian bridge.



**Photo 5.3**  
Example of a Cable Stay Pedestrian Bridge

(Note that the piers are located outside of the bankfull channel and the bridge spans part of the floodplain.)

## **5.6 TIMELINE AND CONSTRUCTION SEQUENCING**

### **TIMELINE**

Due to the size and complexity of this project, it is recommended that the following phased construction approach be used. To the extent possible, efforts have been made to link the river restoration construction phases with the major components of the dam removal and sediment removal activities.

|         |   |
|---------|---|
| Year 1  | Phase 2 begin   |
| Year 2  | Phase 2 end, Phase 2 Design/permitting Begin                                  |
| Year 3  | Phase 3 Design end / Begin sediment removal/ Construct the upper half of CFR4 |
| Year 4  | Continue sediment removal / Construct the lower half of CFR4                  |
| Year 5  | Continue sediment removal/ Construct upper half of CFR3                       |
| Year 6  | Complete sediment removal/ Construct lower 1/2 of CFR3 and lower 1/2 of BFR2  |
| Year 7  | Construct upper half of BFR2, and CFR2  |
| Year 8  | Construct, upper half of BFR1   |
| Year 9  | Remove spillway/Begin construction of CFR1                                    |
| Year 10 | Remove Powerhouse/Construct lower half of BFR1/Complete CFR1                  |
| Year 11 | Rebuild replica of Powerhouse on site above the floodplain.                   |

Since Reach CFR4 is beyond the impacts of the dam and the most upstream reach, it is the most flexible reach. CFR4 could be constructed as early as year 3, or after the construction of the other reaches. The upper half of Reach CFR3 is similar to CFR4 and could be constructed as early as year 3 or after the construction of the other reaches. The excess sediment generated in the lower half of CFR3 is planned for floodplain fill material in CFR2, so it cannot be constructed until at least part of the sediment removal in CFR2 is complete. Likewise, if the excess sediment generated in BFR2 is to be used for floodplain fill material in CFR2, it could not be constructed until most of the sediment removal in CFR2 is complete. The lower part of BFR2, the upper part of BFR1, and CFR2 should be constructed after sediment removal is complete but prior to dam removal so as not to create a fish barrier with Stimson diversion dam. Removal of the spillway and diversion of the water through the Power House should allow the construction of CFR1 to commence. Once CFR1 is complete, the flow can be diverted into the new CFR1 channel and the Power House can be removed and the lower half of BFR1 can be completed.

Typically, it is recommended that construction begin at the upstream end of the project and proceed downstream. Having the dam in place during the construction of the upper reaches will provide a means to minimize passing turbid waters downstream.

## **CONSTRUCTION SEQUENCING**

WCI has developed a construction-sequencing plan based on the project design and past experience with projects of similar scope and complexity. The complete construction sequencing is too detailed for this conceptual design, but is available upon request. General steps for the sequencing are listed below.

- Task 1: Construction Staking
- Task 2: Sort and Distribute Materials in Project Area
- Task 3: Construct Water Diversions
- Task 4: Initial Channel Shaping and Excavation
- Task 5: Structure Placement for Bank Stabilization and Habitat Creation
- Task 6: Final Channel Shaping
- Task 7: Reintroduce Water into the New Channel
- Task 8: Reclamation of Diversion Channels and Floodplain Construction
- Task 9: Revegetation of all Disturbed Areas
- Task 10. Cleanup of Construction Areas

### **5.7 PHASE 2 NEEDS**

The following items would be necessary to validate the CRP and collect the necessary data to proceed with a final design.

- ◆ Develop Digital Terrain Model using survey of existing ground and photogrammetric mapping
- ◆ Bridge Analysis- scour and ice potential determination
- ◆ Sediment Entrainment Analysis
- ◆ Refine Draft Channel Dimensions
- ◆ Finalize Flood Series Analysis
- ◆ Evaluate Land or Easement Purchase (Note: These costs not included in Restoration Plan Cost Estimate.)
- ◆ Evaluate whether restoration or design conforms with remedial action requirements.

### **5.8 PHASE 3 FINAL DESIGN NEEDS**

During completion of Phase 2, final design could be initiated. The design tasks listed here are associated only with the plans and treatments of the CRP and would replace similar design tasks in EPA's proposed remediation plan associated with channel construction in the Area I sediment removal area. The design tasks associated with the remainder of EPA's proposed remediation

plan would need to be completed. The design tasks listed in the following section would most likely be completed on a reach-by-reach basis about two years before the construction is scheduled. Tasks included under the Final Design phase include, but are not necessarily limited to the following:

- ◆ Finalize plan view pattern, longitudinal profile, and cross-section dimensions;
- ◆ Ground truth proposed alignment with Technical Review Committee;
- ◆ Develop proposed Digital Terrain Model;
- ◆ Calculate earthwork and develop construction heap flow charts;
- ◆ Perform channel and floodway modeling (HEC-RAS);
- ◆ Specify material types, quantities, and dimensions by reach;
- ◆ Engineer bank stabilization, grade control, fish habitat, and recreational in-channel structures;
- ◆ Prepare detail sheets for all major design components, including longitudinal profile, plan view pattern, channel cross-sections, and proposed structures and revegetation components;
- ◆ Prepare construction sequencing report, including equipment specifications;
- ◆ Prepare water quality mitigation and dewatering plans for construction; and
- ◆ Prepare and submit CLOMR/LOMR to the Federal Emergency Management Agency and Missoula County Floodplain Administrator.

The final design report would include all appurtenant analyses used to complement the final design report and detail sheets.

## **5.9 MONITORING NEEDS**

The proposed EPA remediation plan includes monitoring for groundwater, surface water (quality and quantity) and biological conditions. It is assumed that the proposed monitoring will accomplish all of the needs for those resources. The CRP introduces several concepts that will also require monitoring to determine performance of the treatments in meeting the objectives and to initiate maintenance, if needed, to bring the performance into compliance with the objectives. The proposed monitoring for the CRP would be in addition to that monitoring proposed in the EPA remediation plan. It would primarily consist of monitoring the channel conditions, including stability and performance, and would occur on the first year of implementation one reach and on every other subsequent over a period of 10 years. The proposed monitoring has been developed over the last several years to meet the requirements of the permitting agencies. In other words, the permitting agencies will require monitoring similar to the proposed plan for the river restoration to be permitted.

To monitor the channel condition, permanent cross-sections and longitudinal profile (LP) stations would be established. Cross-sections would be located in multiple representative pool, riffle, and run habitats. A channel survey, pebble count, and photo point would be completed at each cross-section. The LP stations would be established at channel habitat feature transitions (top or riffle, pool) to quantify channel feature changes. Bank pins would also be installed at selected locations in project and untreated reaches to compare bank erosion and sediment input rates.

Elevation measurements and photo points would also be completed for each structure. Measuring structure and bed elevations over time would improve the understanding of sediment transport, energy dissipation, and habitat maintenance created by the structures.

Vegetation monitoring would include evaluating treated and untreated reaches for relevant attributes such as vegetation composition and cover, utilization, shrub and tree regeneration, and coarse woody debris. Perhaps one, tenth-acre plot placed in representative sites of each project area would provide a sufficient sample. Noting the presence and abundance of noxious vegetation, particularly where weeds have been treated with this project, would be essential to the vegetation-monitoring program.

One of the restoration goals is to improve fish habitat and fish passage through the project areas. The fish population-monitoring program should focus on sampling the project areas. Montana Fish, Wildlife & Parks may also opt to continue with on going radio telemetry studies designed to track native bull trout and westslope cutthroat trout.

At this time, the proposed monitoring program is still in the planning phase. The preceding recommendations are based on standard monitoring techniques. A monitoring program would be critical for evaluating restoration success. Specific monitoring is usually developed during the design and permitting phase of a project.

## **5.10 MAINTENANCE NEEDS**

A maintenance regime would be implemented to address re-vegetation, structure and channel adjustments that may occur following project construction. The proposed maintenance plan includes assessing the project areas 1, 3, 5, 7, and 10 years after the completion of the projects. The maintenance budget would be one percent of the project cost weighted by the length of the project reach. Maintenance may include reconstructing failed structures, adding additional structures, additional vegetation planting, noxious weed treatments or channel modifications.

## **6.0 COST ANALYSIS**

This section will present the data sources, cost assumptions and unit costs for proposed treatments. Actual cost estimates are included in Appendix 6. The cost estimates do not include those costs already covered by the EPA's Proposed Plan for remediation. As discussed in Section 5, some of the EPA's proposed treatments are not necessary, or used in this CRP. The exact cost differences are not possible to determine, however, by comparing the cost estimates presented in Appendix 6 with those from the EPA proposed remediation plan, this differences may be estimated.

This section includes a discussion of how the costs were developed for the restoration cost estimate. More specifically, general information related to cost sources, assumptions, unit costs and contingencies is provided.

It is recognized that landowner cooperation and approval will be necessary in order to assure the success of this restoration project. These cost estimates, however, do not include the costs of land or easements, which may be necessary or appropriate to facilitate the project. These cost estimates also do not include the costs of building a replica of the powerhouse, although this is also contemplated as part of this plan.

## **6.1 COST DISCUSSION FOR CHANNEL AND STRUCTURE PROPOSALS**

### **SOURCES OF INFORMATION**

The Option 3 Cost Estimate prepared by the USACE was used as a baseline for WCI's restoration cost estimate for reach CFR2 and portions of reaches CFR1 and BFR1. WCI's estimate includes costs for three additional reaches, BFR2, CFR3 and CFR4 as well as the remainder of reaches BFR 1 and CFR1. As discussed in Section 2.0, it was determined that the construction of the additional reaches is essential to providing a long-term, comprehensive restoration plan.

Other available information used for the restoration cost estimate included the Draft Sediment/Dam Removal Cost Estimate Report for the Milltown Reservoir Site prepared by EMC<sup>2</sup> dated August 13, 2002. From this report, a topographic map of the site after sediment removal was obtained and used to estimate cut/fill quantities for the restoration cost estimate. In addition, the Clark Fork and Blackfoot Rivers Channel Cross-Section Surveys by Land and Water Consulting, Inc. dated February 1997 was also used to estimate cut/fill quantities. Estimates for re-vegetation and structures were based on WCI's experience with projects on rivers of similar size and complexity.

Whenever possible, unit costs estimated with the USACE Tri-Service Cost Engineering System (TRACES) Project MLTN21 (12/02) were used in the CRP cost estimation. The summary of costs provided by the USACE Government Estimate Total Costs for Option 3- Cost Estimate (12/2002) was used to as a pattern to provide the estimated costs for the CRP.

The Focused Feasibility Study (FFS, June 2001) estimates the total cost for removing Milltown Dam, powerhouse and all associated structures at \$5,096,085 without contingency; this cost was used in the CRP Cost Estimate because the CRP calls for the removal of all these structures. The cost of removing the dam spillway and radial gate, along with some of the mitigation measures necessary to remove the spillway, are included in the EPA remediation plan. Therefore, it is recognized that there is some duplication of costs in the two plans, which can be accounted for if the two plans are integrated as one plan.

### **ASSUMPTIONS AND UNIT COSTS**

Unit costs for earthwork were divided into three categories and derived from the USACE estimate. A unit cost of \$3.93/cy was deemed appropriate for on-site (localized) cut and fill



earthwork within a reach. The unit cost was derived from USACE unit costs for excavation of \$3.32/cy plus grading at an additional \$0.61/cy, for a total of \$3.93/cy. This is consistent with construction costs on past restoration projects managed by WCI. A unit cost of \$3.10/cy was applied to the quantity of fill that must be imported to those reaches that have a net deficit of material. This cost was taken directly from the USACE estimate and is based on similar assumptions. A unit cost of \$3.32/cy was applied to the quantity of excess fill that must be excavated and exported from those reaches that have a net surplus of material. This cost was taken directly from the USACE estimate and is based on similar assumptions as well. When excess gravel is taken from one site and hauled to another site and graded, as is the case with excess from CFR 3 hauled to CFR 2, the costs are additive; i.e. \$3.32/cy to excavate and load plus \$3.10 to haul and grade equals \$6.42/cy total.

In two reaches, the unit costs for earthwork deviate from unit costs applied to the other reaches. For Reach CFR 2, the cost of grading the Area III sediments to construct the floodplain in the same reach, lower unit costs were applied. In this case, the unit cost of \$2.71/cy that was used for growth medium grading from the USACE estimate was used for CFR 2. For CFR 3, due to the uncertainty of toxic sediment location concentrations, all unit earthwork costs in this reach were increased by 25% to account for the possibility of additional soil treatments and/or material handling costs.

An additional line item was added to the cost of CFR 1 to account for the cost of removing the powerhouse and related structures. This cost was taken directly from the Dam Removal Cost Estimate prepared by USACE as referenced in Section 6.1.

Structure costs were determined based on the total quantity of materials that would be required for each type of structures multiplied by the estimated number of structures in each Reach. Since a good rock source exists close to the project area, it was assumed that transportation costs would be lower than normal. However, large rock is expensive to quarry and transport to the site. It is estimated that the average cost for rock delivered to the site would be \$40/ cubic yard. This unit cost is based on WCI's past experience with the average cost for rock from the same quarry hauled less than five miles.

The other material that would need to be transported to the site would be large wood. A total quantity of trees was determined and an average cost of obtaining and transporting those trees to the site was estimated. An average cost of \$125 per standard tree and \$250 per large tree was used in the cost evaluation. This unit cost is the average cost for WCI projects over the last two years for gathering and transporting whole trees. The actual cost can vary greatly depending on availability of the trees and distance to transport.

Equipment time was also estimated for each structure and multiplied by the number of structures in each reach. The total costs for materials and equipment time was determined and summarized for each reach. An example of a cost analysis sheet for each structure is in Appendix 8.

Staking and survey costs are estimated by WCI's Professional Land Surveyor (PLS), with experience in surveying and staking projects of this size. Erosion control fencing used unit costs from the USACE TRACES cost estimate (12/2002). Mobilization and cleanup was estimated

using the number of pieces of equipment times an average cost of \$500 per piece for a typical mobilization into and out of a project site. Cleanup was assumed to be double the demobilization cost. The Project Management, Phase 3 Final design, Construction Oversight and Permitting used the USACE cost percentages based on total project size. WCI personnel estimated Construction Oversight and Design separately and the results were similar to the USACE percentages, lending validation of the assumptions.

WCI professionals who perform data collection and prepare monitoring plans for rivers of this size estimated the Phase 2 task costs and monitoring requirements for each reach. These estimates are based on actual estimates of the tasks to be completed. The details of the actual cost estimates are available upon request.

Maintenance costs are assumed to be one percent of the total project cost every other year for five years following the project implementation. This assumption is valid based on WCI's past experience in implementing projects on rivers of this size.

Miscellaneous costs were usually the most difficult to determine, usually because little information is known about the design or construction of item in question. For example, an estimate of \$25,000 was assumed for moving the building of unknown purpose in reach BFR 2. This cost is only an assumption without knowing the purpose of the building or how far it may need to be moved. These cost items are useful more as a placeholder to be validated in Phase 2 and 3 of the CRP. Most of the items have a very small cost when compared to the total cost for the completing the reach and would be covered by the contingency. Where miscellaneous costs can be validated, it is noted in the individual cost estimate for the reach.

## **6.2 RE-VEGETATION COST REFERENCES AND ASSUMPTIONS**

### **STRATIFICATION OF PROJECT AREA**

The project area has been subdivided on the basis of geomorphic setting and re-vegetation treatment differentiation. The stratifications include streambanks, floodplains, wetlands, alluvial depositional areas, Holocene terraces and other disturbed upland areas. The proposed re-vegetation prescription "package" for each subdivision has unique attributes. The individual areas were delineated through a combination of aerial photo interpretation and post-construction landscape position associated with the conceptual design. Another category was "other disturbed upland areas" to account for constructed slopes, borrow sites, roadways, etc. These areas were determined based on professional experience with previous large river restoration projects.

### **AREA TO BE TREATED**

The areas to be treated within each of the geomorphic landforms were determined by comparing the existing vegetation conditions to the anticipated post-construction conditions. For example, in areas where the channel was going to be relocated from its present location the resulting "abandoned channel" would be void of vegetation and the soils would have low inherent fertility and be coarse-textured with low water holding capacity. Based on native plant community of typical undisturbed lands with similar characteristics the re-vegetation prescription was developed. AutoCAD was utilized to determine the acreage of the landforms within each of the stream reaches. The acreage was multiplied by the desired tree/acre stocking to determine the

total number of containerized plants and cuttings required. The actual acreage for each land type is included in the cost estimates for each project reach.

### **CONTAINERIZED PLANT MATERIALS AND CUTTINGS**

The costs for containerized plants and cuttings are based on WCI's considerable re-vegetation experience and use of state-of-the-art planting equipment and technology. The cost estimate for plant materials was \$11 per containerized plant, \$9.00 for wetland plants and \$3.50 for cutting. The numbers of plants and cuttings in a given prescription is based on the desired spacing. For example, a 10' x 10' spacing requires 436 plants per acre. The cost per plant and cutting are consistent with other large projects and includes seed collection and seedling propagation, inoculating the containerized plants with beneficial soil microbes, mobilization of plants and equipment, and installing the plants/cuttings. The greatest success rate for the cuttings is attained with two cuttings per planting hole. The costs also include the re-vegetation of sites previously considered to be "unplantable" such as riprap, cobble, etc.

### **TRANSPLANTS AND SOD**

Strategically placed sod mats are effective for armoring constructed stream banks and abandoned channels, and provide "instant" vegetation. Transplants of woody plant placed in and around stream bank structures add to structure stabilization.

The cost includes both the salvage sod and transplants during construction activities and importing these materials from dedicated collection areas. The area to be treated with sod and/or transplants was calculated from AutoCAD generated data. The length of bank to be sodded was converted to acres for consistent costing. The cost of \$3,250 per acre is based on WCI's records and includes mobilization, harvesting, transporting and placement of the sod/transplants. The cost of temporarily storing and caring for sod and transplants is also included.

### **SEEDING**

The seed mix consisting of native species would be applied at a rate that provides a surface coverage of approximately 90 - 100 seeds per square foot. The numbers of seeds per pound varies considerable by species; therefore, the actual quantity of seed needed is dependent on the final mixes approved for the project. All seed mixes would be certified as being noxious weed free. Native seed mixes vary but average around \$8 per pound with an application rate of about 25 pounds per acre.

Depending on terrain and access the seed would be applied by a combination of manual and mechanical techniques. A non-persistent "nurse" or "cover" crop would be seeded in some areas to facilitate the establishment of the native species.

### **HYDROMULCHING**

Hydromulching is a very effective method of uniformly applying seed, mulch, fertilized, tackifier, soil organisms and other soil amendments and would be used extensively to accomplish the revegetation. The water-based slurry is sprayed directly on disturbed sites. Hydromulching is also an effective at controlling localized erosion. The inoculants would closely replicate local

microbial populations. The organic fertilizer would provide a long-term source of nutrients and add humus to the soil. The costing includes high quality wood fiber mulch and organic based tackifier. The cost of \$2,100 per acre includes mobilization, all products and application. Acreages were calculated using AutoCAD.

### **INVASIVE VEGETATION INCLUDING NOXIOUS WEEDS**

Noxious weeds and other invasive vegetation are well established within the project area and, despite recommended mitigation efforts, it is inevitable that weeds would establish to some degree within areas disturbed by construction activities. A post-construction herbicide treatment program of disturbed areas would be necessary. Annual treatments over the three to five years following project completion would be required. The costs are based on an aggressive program of all disturbed areas and are based on industry standards. Post-treatment monitoring will be the best indicator of mitigation measures and control treatments. Monitoring will validate the accuracy of the cost estimated. The cost of treating noxious weeds is included in the semi-annual maintenance cost estimate discussed in Section 5.10.

### **6.3 CONTINGENCY**

The restoration cost estimates were prepared without existing detailed ground surveys or a definitive ground surface after the excavation of reservoir sediments. Since approximately 55% of the restoration cost estimate is earthwork and is highly dependent on information developed by others, there is a significant level of uncertainty with the cost estimate. Up to this point, several assumptions and contingencies have been applied to the estimates and information used by WCI. Therefore, a contingency of 25% has been applied to WCI's estimate. For projects with significant uncertainty and limited information such as this, a contingency of 15% to 35% is not uncommon. For example, the MCACES cost estimate (EMC2, 10/31/2000) uses a contingency of 35% for the Dam removal costs. That document states that for feasibility/reconnaissance level estimates, a contingency of 25% is normally used.

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